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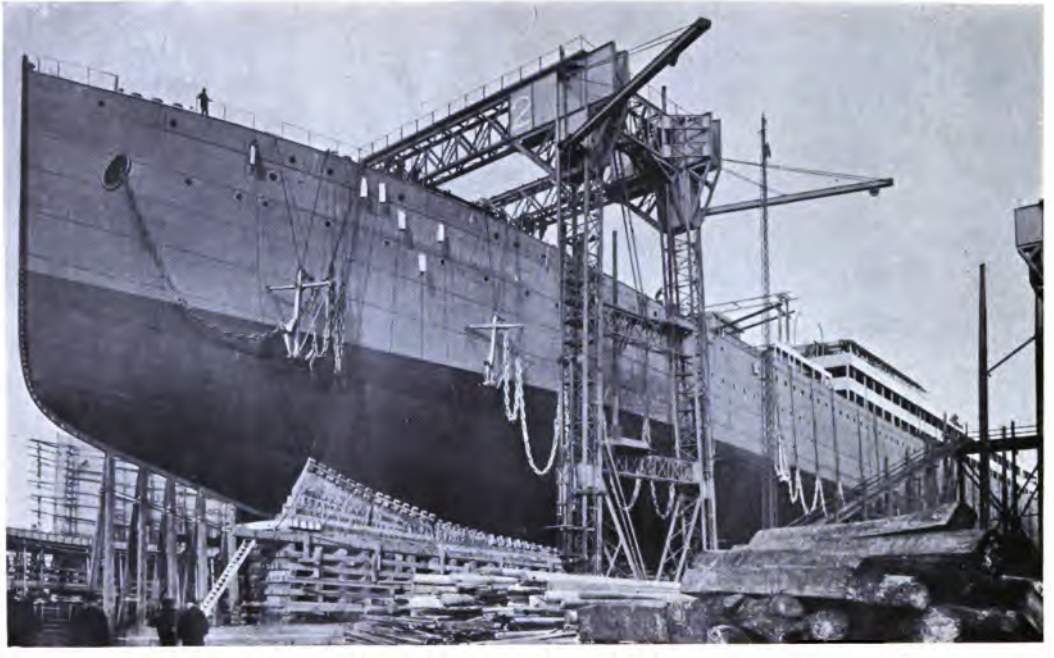

WHITE STAR LINER "BALTIC" ON THE STOCKS AT BELFAST, READY FOR LAUNCHING

THE SHIPBUILDING INDUSTRY

ITS HISTORY, PRACTICE, SCIENCE AND FINANCE

BY

DAVID POLLOCK

M.I.N.A., M.I.E.S.

AUTHOR OF
"MODERN SHIPBUILDING AND THE MEN ENGAGED IN IT"
"SHIPBUILDING," AND ALLIED SUBJECTS IN
"CHAMBERS'S ENCYCLOPÆDIA"

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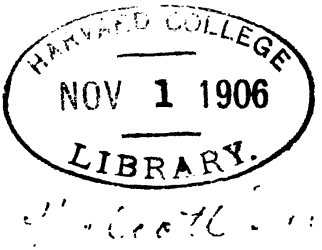

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CONTENTS

CHAPTER I

PAGE

ANCIENT SHIPS AND EARLY STEAMERS 1

CHAPTER II

DEVELOPMENT OF THE MODERN STEAMSHIP . . 49

CHAPTER III

SHIPBUILDING IN UP-TO-DATE SHIPYARDS . . . 81

CHAPTER IV

EVOLUTION IN STRUCTURE AND TYPES OF SHIPS . 120

CHAPTER V

TONNAGE-PRODUCING DISTRICTS AND COUNTRIES . 168

INDEX 193

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LIST OF ILLUSTRATIONS

	FACING PAGE
WHITE STAR LINER "BALTIC" READY FOR LAUNCHING AT MESSRS. HARLAND AND WOLFF'S, BELFAST .	*Frontispiece*
DOUBLE-BOTTOM STEAMER ON THE STOCKS AT MESSRS. JOHN BROWN AND CO.'S, CLYDEBANK	52
DIAGRAM ILLUSTRATING THE EVOLUTION OF THE CUNARD LINER FROM 1840 TO 1905	68
CUNARD LINER "CAMPANIA" ON THE STOCKS AT FAIRFIELD	74
INTERIOR OF EXPERIMENTAL TANK AT MESSRS. WILLIAM DENNY AND BROS.', DUMBARTON	82
MODEL TRUCK IN MESSRS. WILLIAM DENNY AND BROS.' EXPERIMENTAL TANK	86
FRAME-BENDING BLOCKS AND PLATE-BENDING MACHINE .	90
CUNARD LINER "CARONIA" ON STOCKS AT MESSRS. JOHN BROWN AND CO.'S, CLYDEBANK, SHOWING CELLULAR BOTTOM AND SIDE FRAMING	92
PUNCHING, SHEARING, AND FLANGING MACHINES . .	96
RIVETING BY HAND AND BY HYDRAULIC AND PNEUMATIC POWER	100
CRANE EQUIPMENT OVER BUILDING BERTHS . . .	106
FITTING-OUT CRANE OF "HAMMER" OR CANTILEVER TYPE .	118
TURRET STEAMER IN FRAME AT MESSRS. WILLIAM DOXFORD AND SONS', SUNDERLAND	130

FACING PAGE

TURBINES OF "VICTORIAN" UNDER CONSTRUCTION AT MESSRS. WORKMAN, CLARK, AND CO.'S, BELFAST . 138, 140

ENGINE-ROOM OF TURBINE STEAMER "MANXMAN" . . 146

ALLAN LINER "VICTORIAN" ON STOCKS IN MESSRS. WORKMAN, CLARK, AND CO.'S, BELFAST . . . 152

COMING TURBINE CUNARD LINER OF 25 KNOTS SPEED . . 160

FITTING-OUT CRANE OF DERRICK TYPE AT MESSRS. BLOHM AND VOSS'S, HAMBURG 184

SECTIONAL VIEW OF INTERIOR OF CUNARD LINER "CARONIA" 192

PAGE
140
146
152
160
184
192

THE SHIPBUILDING INDUSTRY

CHAPTER I

ANCIENT SHIPS AND EARLY STEAMERS

BY what means prehistoric man, or even men in the antediluvian age, crossed rivers or navigated lakes, forms an inquiry which has had resistless fascination for studious minds all down the course of time, and much learning has been expended in deciphering, from ancient sculptures or rock-drawings; from Saga and Edda literature; and from exhumed relics discovered from time to time in various parts, precise information on primeval man's medium of water transport, and on the subsequent evolution of the raft, the dug-out, the coracle, the canoe, the rowing galley, the sailing ship for coasting and over-sea service. We can only here, in the most superficial way possible, touch on outstanding and comparatively modern features of such lines of inquiry.

Canoes, hollowed out by fire and by stone implements from the solid tree-trunk, have been found, more or less completely preserved, in many parts of the world, and in some of the more uncivilised parts

these may still be seen in use, as will also the "coracle" or boat made of wickerwork with a covering of hide. The coracle of Wales is well known, and in western Ireland the "curragh" is still in use; while in South America, and other parts of the world, the balsa, made of reeds elaborately woven, and rendered watertight by pitch or bituminous substances, are considered quite worthy of modern ingenuity and skill in producing. Ancient canoes have repeatedly been found on the banks of British rivers, notably on the Clyde, where so recently as the autumn of 1903 one was unearthed at Dalmuir while excavations were proceeding in connection with Glasgow's new sewage works.

When and where it was, precisely, that boats began to be *built*—that is to say, made up of the two main components, framework and planking—it is difficult, if not impossible, to determine. The more generally regarded, though perhaps apocryphal, starting-point in history from which to trace the course of ship development is the building of Noah's ark. Whether from the accumulated knowledge and experience of the intervening centuries we do, or do not, freely interpret the biblical story regarding this momentous work according to the facts of modern life, Noah's ark still undoubtedly forms our first conception of a ship. Even after we have learned to shed our infantile and very literal belief in its miraculous carrying capacity, and in the architectural verity of that peculiarly roofed-in structure beloved of the nursery, there remains to us a settled reverence and wonder for the biblical creation as regards many

of its fundamental features. Even modern designers have a professional respect for the Ark's proportions, which were 300 cubits (450 feet) in length—assuming, as is generally done, the cubit to have been 18 inches—50 cubits (75 feet) in breadth, and 30 cubits (45 feet) in depth, and some have based designs upon the same following. This, however, has not necessarily resulted in a successful vessel for modern or general everyday purposes. The great antediluvian ship was reputedly intended for one very special purpose, and that involved the question of carrying capacity and leisurely floating on the face of the waters, rather than safely speeding through or upon them. She fulfilled her desired functions in a faultless way, of course, and although her living freight was of unspeakable value, her subsequent "grounding" was scarcely regarded as a calamity, as such occurrences usually are nowadays, with our fully developed Board of Trade regulations and inquiries and marine insurance policies.

Seriously, however, we read that the Ark was "built of gopher wood" and "pitched within and without with pitch." The gopher wood is the cypress, which in after ages, with the cedar, was the favourite shipbuilding timber of the Greeks (for the wetted or underwater parts of a vessel especially), largely on account of their finding that it was not liable to shrink and cause leakage. In this apparently intuitive fixing upon the best and most suitable wood to resist the effects of water wear and pressure, which only long experience afterwards had taught the cultivated Greeks, we may perhaps see convincing testi-

mony to the divinely inspired prescience of Noah, the "father of ship builders."

However that may be, the earliest Egyptian drawings show boats constructed of sawn planks, and having sails as well as numerous oars. About 1260 B.C. their boats were built of acanthus wood, "pinned" with wooden nails, and caulked with papyrus, as in later times oakum came to be used. So far as ancient sculptures contribute to the question, the ships of ancient Greece and Rome appear to have been open or undecked—at least in the middle portion—and to have been built with keel, ribs, and planking, and to have been strengthened crosswise by the benches on which the rowers sat. Pine, cedar, and other light woods were employed in the boats which the Romans built for ordinary use and pleasure, but in the case of their war vessels, oak was the material generally used, clamped strongly with iron or brass, and fitted at the bows with metal beaks for offensive use as "rams."

Considering the limited knowledge of the ancient shipbuilder as to what ocean navigation demanded, and the restricted nature of his material and appliances, he achieved remarkable results. The ships of the Phoenicians, for example—the intrepid merchants and navigators from the land surrounding the cities of Tyre and Sidon—were notable productions, and known on many seas. As seafarers the Phoenicians were unrivalled, and the "Merchants of Tyre" had commercial relation with many countries. They traded with India for King Solomon 1000 B.C., and their sturdy ships sailed all over "The Great Sea"

(Mediterranean) and out through "The Pillars of Hercules" (Straits of Gibraltar), across the Bay, to our own shores, and to the delta of the Rhine, and further. In Eastern seas they had rivals, as navigators, in the Cretans and Chinese, the latter of whom are, as is well known, credited with the first use of the loadstone for navigation, and indeed with the invention of the mariner's compass.

Considering their size, these ships of the Phoenicians must have been well designed and built to perform such voyages, but even greater skill and painstaking effort must have been expended later in the production of the trading ships and war galleys of the Carthaginians, as well as of the Romans, who copied from and improved upon them. The great fighting galleys of Greece and Rome, with which many high-pitched battles were fought, were 100 feet long and over, and carried, as the Roman title *Triremes* indicates, three tiers of oars. The rowers were beneath the fighting deck, out of the way of the soldiers who occupied it, and they rowed in time to music or song with great unanimity. The galleys were built higher aft than forward, and had full round lines, but with the deadly beak or ram at the prow to cut into the opposing ship. Their rig seems to have consisted generally of one mast, placed nearly amidships, carrying one large square sail. One instance of the fact that vessels of large size and capacity were built and successfully navigated in the days of Rome's ascendancy may be referred to. The ship used by Constantine to convey the largest obelisk of Heliopolis to Rome carried, besides the

obelisk (which weighed 1,500 tons), some 1,140 tons of grain as packing and ballast; in all, a dead-weight of 2,640 tons. Cleopatra's Needle, on the Thames Embankment, was packed in much the same manner for transit to this country, and the romance of the craft in which it was packed getting adrift on the voyage and being picked up again by a passing steamer, will be remembered.

Rome's decline brought other nations or races to the front as colonisers and sea-adventurers. The hardy Norsemen went far afield, and their association with shipbuilding was therefore very intimate, and had to be progressive. Their ships were meant, even more than the stately galleys of the Empire, for aggressive occupation, and in wider and rougher fields of enterprise. Like the shipping of to-day, the ships of the Vikings had to fulfil four distinct purposes. There were war vessels, cargo carriers, passenger or ferry boats, and craft of light and fine design intended for rapid sailing—the prototype of the modern yacht.

It was in their "serpent" or war vessels that the highest development of the naval architecture of the Vikings was attained. These were generally constructed of oak, were clinker-built (that is, the lower edge of one row of planking overlapped the top edge of the row next below), and were propelled with sails or oars. A notable example of these ancient craft was discovered in a "tumulus," or burial mound, at Gokstad, near the entrance to the Christiania Fiord, in the year 1880. It was in splendid preservation, and as exhumed is still treasured in the Christiania University. It is 78 feet long, 16 ft. 7 in. beam, with

a depth of 5 ft. 9 in., the keel being 57 feet in length and 14 inches deep. On either side a row of shields had existed, designed to form a sort of raised bulwark to protect the rowers, who tugged in twos and threes at the 25-feet to 40-feet oars or sweeps, sixteen a side, which projected through holes in the top sides. These holes were closed by sliding oak shutters or panels in bad weather, or when the vessel was under sail. The mast was a substantial spar of pine 40 feet high, and probably carried a square sail.

The measure of length applied to these craft was the number of seats each contained. Thus the "serpent" of Canute the Great was a sixty-seater, which, allowing, say, 3 ft. 6 in. between the seats, would, with the stem and stern portions, give a total length of 300 feet or over. Another example, of which the Saga and Edda literature tells us, was the *Long Serpent* of Olaf Tynggvason, which was quite 180 feet in length. It was divided by bulkheads between the rowing benches into thirty-four runs or rooms, a half-room accommodating eight persons, making, with the forecastle, etc., quarters for over 700 men. Usually, except in very high ships, there was no laid deck, save the raised forecastle and poop.

The Gokstad example of the ships of the Vikings exhibits lines very much finer than those of the Roman ships, and very symmetrical, showing that the northern designer of over a thousand years ago had considerable skill in modelling. Readers who may be especially interested in this subject, and desirous of learning more regarding "Shipbuilding a Thousand Years Ago," may be referred to a paper with

that title read before the Institution of Naval Architects in 1881, and contained with illustrations in the volume of *Transactions* of this body for that year. Replicas of the Gokstad vessel, it may be added, were constructed, with original fulness of detail, and shown at Chicago Exhibition in 1893, and at Antwerp Exhibition in the year following. So recently as August, 1903, it was reported from Norway that another Viking ship, probably the same size as the Gokstad vessel, had been discovered in a burial mound near Toenberg. Only the sternpost had then been uncovered, and as the craft lay at a great depth and the season was unfavourable for excavation, the part already laid bare was again covered up until the resumption of operations later.

The size of ships did not increase very much, if at all, from the time of the Romans until as late almost as the seventeenth century. Alfred the Great, the true father of Britain's Navy, kept the Viking warships in check by galleys, which, although of considerable dimensions and powerful manning, were only adapted for inshore service. The "large ships" in which Richard Cœur de Lion in 1190 conveyed his forces to the Crusades were of but small dimensions, depending chiefly for propulsion, not on rowers, but on sails. Columbus made his first voyage to the New World in the *Santa Maria*, of 90 feet keel and 29 feet deep, along with two small, undecked caravels, although other accounts say the vessels in which he and his companions discovered America in 1492 were fully decked, had four masts, and each a crew of forty men.

Henry V. during the early part of the fifteenth century ordered the construction of several large ships, the wonder of their time, one of which is recorded to have been about 165 feet extreme length, 112 length of keel, and 46 feet beam. Henry VII., and still more Henry VIII., did much to encourage ship construction both for war and commerce. In the reign of the former the finest specimen of British shipbuilding, the *Henry Grace à Dieu*, or "*Great Harry*," was built (1514), which, properly speaking, was the first ship of the English Royal Navy. She was probably 138 feet long by 38 feet broad, and of 1,000 tons burden. Details of her armament are recorded. It included 120 guns, mostly very small, but four of which were sixty pounders and three thirty-three pounders. Her cost was about £8,700. To Henry VIII. belongs the honour of having laid the foundation of the British Navy as a distinct service. He constituted the Admiralty and Navy Office, established the Trinity House, and the Dockyards of Deptford, Woolwich, and Portsmouth, fixed regular salaries for the admirals, captains, and sailors, and made the sea service a distinct profession. In Scotland James IV. formed a dockyard at Newhaven, near Leith, on the Forth, and in 1511 ordered the building of the *Great Michael*, "ane varie monstruous great schip," which required such a mass of timber for her construction that "she waisted all the woodis in Fyfe except Falkland Wood, besides the timber that came out of Norway." This "varie monstruous great schip," it would appear, measured 240 feet long by 36 feet beam—not very great as

things go nowadays; but it seems that she had massive sides of oak 10 feet thick, "so that no cannon do at her," which, perhaps, is sufficient to justify the obvious hyperbole respecting the "waisting of all the woodis of Fyfe."

From old prints it is seen that vessels of the sixteenth century, and indeed for long afterwards, were very short and broad, and highly built at the ends, especially so at the stern. The sterns of the galleons forming the Spanish Armada (1588) were of immense height, and in the northern gale which proved so disastrous to that huge fleet, no doubt the high sterns aggravated the predicament, and rendered the ships quite unmanageable. Even at the end of the eighteenth century the fighting ships, or "wooden walls of Old England," were very short, broad, and high—necessarily so in the larger ships, in order to carry their three tiers of guns.

In 1620 the most notable ship of the English Navy was the *Prince Royal*, 140 feet long, 44 feet beam, and 1,200 tons burthen. She cost £20,000, and carried 55 guns. Fifty years later saw the advent of the *Sovereign of the Seas*, 168 feet long, 48½ feet beam, and 1,640 tons burthen. She carried 100 guns, the heaviest projectile weighing 60 lbs. The estimated cost of this vessel (whose design by Phineas Pett, afterwards referred to, was the subject of severe criticism by naval experts of the period) was £13,680; but, unfortunately, the actual cost approached £41,000, representing probably over £300,000 at present values. In connection with the production of this ship, the Masters of Trinity House

declared that the construction of a three-decker was "beyond the art or wit of man," and that there was no port, "the Isle of Wight only" excepted, in which she could ride, and no ground tackle which would hold her.

The main principles of wood construction were even then well understood, but increase in the size of ships was slow. Scarcely any advance had been made in this respect during the reign of Elizabeth, notwithstanding that ships were then built in greater numbers, and that her reign was pre-eminently the period of daring navigators. Elizabeth's successor, the first of the Stuarts, did much to develop both the Royal Navy and the Mercantile Marine. He appointed commissions of inquiry into naval affairs, and granted a new charter to the East India Company, which had been founded by Elizabeth in 1600, and which during the following ten years built some notable ships: one, the *Trades Increase*, being of 1,200 tons, and the largest merchant ship up till that time constructed.

With a view to raising the standard of knowledge and practice amongst shipbuilders, James I. granted a charter in 1612 to the Shipwrights' Company, which ancient body still exists, and membership of which is a coveted honour by modern shipbuilders and naval architects. This corporation had jurisdiction over all shipbuilders in the kingdom, and its first President was Phineas Pett, Master Shipwright of Woolwich Dockyard, who subsequently, as already mentioned, designed—in face of the scepticism of established interests like the Masters of

Trinity House, etc.—the *Sovereign of the Seas*. By him and by his son Peter, as well as by Sir Anthony Deane, naval architecture was greatly advanced during the seventeenth century. Skill and thoroughness in ship carpentry as a craft continued to be maintained, but there was little advance in improving structural methods, and none whatever in applying scientific principles to the design and growth of ships. For quite a century, science (and the advancement which it alone could suggest and materialise) was a dead letter in British shipbuilding. All the scientific spirit and talent then in evidence were evinced by the designers and builders of other countries—*e.g.* France, Spain, Sweden, and Denmark—and the ships produced in these countries, both for naval and mercantile purposes, were greatly superior as regards size, speed, and sea behaviour to the productions of Britain.

Methods and system in the Royal Dockyards had become so stereotyped that for imperfections which were only too obvious—such as the lack of both longitudinal and transverse strength—no remedies were apparently forthcoming, when at length one emerged who had courage to break away from conventional lines, as well as the requisite scientific knowledge to initiate, and practical skill to develop, improved methods of construction. Beginning as an apprentice shipwright in the dockyards, and rising to the position of Surveyor of the Navy, Mr.—afterwards Sir—Robert Seppings, during the first two decades of the nineteenth century, boldly introduced new features into the conventional hull structure which

made the way thoroughly clear for increase in the size and power of wood ships. To counteract the effect of "hogging"—that is, the dropping of the extremities of the ship relatively to the middle—he associated with the transverse frames, an inner framework of ties and "riders" arranged diagonally. A still more important departure he made was the use of the "filling pieces," introduced between the ordinary frames up to some distance above the bilges. Occupying as they did the whole space between the frames, and corresponding with their outside curvature, these fillings not only afforded immense assistance to the framework in resisting the tendency of the ship to "hog," but were of value also in safeguarding the ship in the event of damage to the outside bottom planking. Under Seppings' régime other improvements were made in the mode of fitting and connecting ("scarfing") items of the hull structure, and what was more notable still, this bold shipwright advocated, and eventually brought about, a reduction of the long beakheads and lofty square sterns which had for centuries been the approved "good form" for British warships. The results of Seppings' improvements were well exemplified in those towering three-deckers, long the pride and glory of the British Navy, and in the staunch and graceful merchantmen known on every sea. Unfortunately that same firm-rooted pride in naval productions of the times stood in the way of further advance in later days, when a less satisfied complacency would have inspired greater idea of, and effort after, more all-round advancement in shipbuilding.

Wood shipbuilding, however, is now a thing entirely of the past in the Royal Dockyards of Britain, and is of the smallest importance in private mercantile shipyards, and has, in short, so fallen into desuetude for anything but the tiniest of coasting and fishing vessels, that the industry has become mainly a matter of historic interest. It would be idle, therefore, to pursue the subject here with a view to conveying any idea of what the art of shipbuilding in wood consists, although, incidentally, contrasts may be drawn between the practice in wood and in iron when work in the modern shipyard is being treated of. But before leaving the subject here, it may be mentioned that in Canada and the United States (in the State of Maine especially), even with the great forward movement in metallic shipbuilding which has taken place in these countries within recent years, a very large proportion of the new shipping built there still consists of wood. In the same way—and although anticipating the story of development somewhat—it may here be convenient to note that the *Adriatic* of the Collins Line of steamships (which, as we shall see later, was built in 1854 to compete with the Cunard Line) was the largest wood ship ever constructed, being 346 feet in length, and of very heavy build, having solid watertight bulkheads. She was, in fact, altogether beyond the then recognised standard rules for shipbuilding. Still further anticipating, it is convenient here to state that so recently as 1898 a wood steamer 330 feet long and 43 feet beam was built on Lake Michigan for freight service on the great lakes. This steamer, the *Thomas Cranage*, was built of

Michigan white oak throughout, except the white pine deck planking, having steel belts fitted to a limited extent to tie the framework together. With triple expansion engines, and modern boilers providing steam at 160 lbs. pressure, driving a single propeller, this vessel, if still afloat, is probably the largest wooden steamer in the world, and forms a remarkable blending of what is newest in modern marine engineering practice with a hull structure which most shipbuilders and owners, in this country at least, consider thoroughly obsolete!

The idea of utilising and applying mechanical power to the propulsion of ships must have originated at a very early period in the world's history, and been conceived, and partially realised perhaps, in different quarters of the world either at different periods or concurrently. The Egyptians are represented in old sculpture records as having employed oxen on board their ships to turn wheels as propulsive agents, and the galleys of the ancients with their equipment of slave labour, and the manual wielding of numbers of oars, represent a stage in the evolution of "power" propulsion. Manual power gave way in the minds of inventive and resourceful navigators to fuller utilisation of sails and nature's forces, and this was followed, naturally and gradually, by ideas of the application of mechanical apparatus.

The steam engine—that mightiest of factors in the evolution of the ship and its propulsion, as in other matters on land—was an accomplished thing, and fairly familiar, before it began to be applied on any practicable scale to ocean navigation. Suggestions

for, and partially successful efforts at, employing steam as the motive power were plentiful long before this stage had been reached, but a bare enumeration of these is all that need be given here. The earliest attempt to propel a vessel by steam is claimed by Spanish authorities to have been made by Blasco de Garay in the harbour of Barcelona in 1583. In 1690 Dionysius Papin proposed to use his piston-engine to drive paddle-wheels to propel vessels, and in 1707 he applied the steam engine, which he had proposed as a pumping engine, to drive a model boat on the Fulda, at Cassel, and was about to despatch the same —"a vessel of singular construction," as records of the time put it—when the local boat- or "watermen," thinking they saw in the embyro steamship the ruin of their business, attacked the vessel at night and utterly destroyed it. Papin, it is said, narrowly escaped with his life, and fled with all his unfulfilled ideas as to establishing steam navigation, to England. In 1736 Jonathan Hulls took out an English patent for the use of a steam engine (Newcomen's modified) for ship propulsion, proposing to employ his steam-boat for towing purposes, and published a pamphlet describing his ideas, and illustrating them with a plate, which is historical. There is no positive evidence that Hulls ever put his scheme to the test of experiment. Bernouilli, and others in France, and in Switzerland—all Academy savants—wrote essays on "the best means of impelling vessels without wind," in which they utilised the Newcomen engine, but it was not until 1770, when an American —William Henry—on a visit to England, had his

attention attracted to the improved engines of James Watt (then new, and the subject of discussion in every circle), that some definite promise of final success with the problem emerged. Henry constructed several model steamboats and tried them on the river near his home at Lancaster, Pennsylvania, but with indifferent success. Among the friends visiting Henry at times were John Fitch and Robert Fulton—the latter then twelve years old—both of whom may have in this way received their earliest suggestions of the feasibility and importance of the application of steam to navigation.

The improvements made in Watt's steam engine about this period, especially that of the separate condenser in 1778 (first applied in 1769), and the employment of the crank a few years later, rendered it additionally suited for application to the propulsion of vessels, and various minds were set upon the fascinating problem. In France, the Marquis de Jouffrouy and others built and tried several experimental craft, the last in 1783; but, through petty jealousy rather than inherent defects, nothing tangible or permanent resulted. In America, in 1785, John Fitch and James Rumsey were engaged on the problem, and in 1786 the latter succeeded in driving a boat at the rate of four miles per hour, against the current, on the Potomac, at Shepherdstown, West Virginia, in the presence, it is said, of General Washington. In 1787 Fitch put a first steamboat on the waters of the Delaware, and in April, 1790, another boat, with various modifications in the machinery, made a speed of seven miles per

hour. In 1790–91 he commenced another steamboat, the *Perseverance*, which was never completed: the wearying fights with rival claimants and different States over questions of patent rights proving too much for him! He went to France in 1793, but in 1796 was again back in New York, experimenting with a little *screw* steamer, and was still experimenting when he went to Kentucky State, where death put a period to his efforts. He was wont to assert that "The day will come when some more powerful man will get fame and riches from my invention, but no one will believe that poor John Fitch can do anything worthy of attention"; and this might have been, and in effect was said, with equal truth by later experimenters on both sides of the Atlantic. John Stevens, of Hoboken, another of the American patentees and experimenters with steamboats, not only sought to apply the paddle-wheel—the natural and fitting substitute for the oar—but is claimed by his descendants to have been—in 1802—the first to use screw propellers for the propulsion of ships, and to have actually fitted a vessel with *twin screws*, which, in 1804, crossed the Hudson River at a speed of six miles per hour. In 1808 he built, in conjunction with his son, the *Phœnix*, which accomplished a voyage from New York to Philadelphia, thus navigating the Atlantic from Sandy Hook to Cape May. From this event he is regarded by some as the pioneer of steam navigation in the open seas.

It testifies curiously to the largeness of the world in those days, or rather to the want of intercom-

munication prior to the final advent of the steamboat, to consider that, in spite of all these efforts involving the application of steam, it was with manual power that Patrick Miller, a retired Edinburgh banker, whose name is always associated with the permanent initiation of steam navigation in this country, began, in 1785–88, his experiments on the lake at his estate of Dalswinton, Dumfriesshire. The credit of suggesting the application of the steam engine as then known to the purposes of propulsion is claimed for a Mr. Taylor, who was tutor to his sons, but as William Symington, an old school companion of Taylor's, and at that time a mechanic of skill and ingenuity employed at the Wanlockhead Lead Mines, was appealed to in the matter, the credit claimed for Taylor and for Miller of "inventing" the steamboat may largely be discounted. Symington, again, doubtless benefited from his knowledge of the mine engines which had for some years been turned out by James Watt at Soho Works, although we read that in 1787, just prior to the time of Miller and Taylor's needs, he had patented "a new invented steam engine on principles entirely new." The result, at any rate, of the efforts of the three men whose names are thus usually bracketed together in connection with the introduction of steamboats, was that partial success was attained on Dalswinton Lake in 1788 with a vessel fitted with an engine actuated by steam.

These early, and perhaps hackneyed, annals, which are given with brevity, and it is hoped accuracy, seem necessary in this work, because it is too frequently the practice in popular books on the subject

to treat of the conception as well as the actual initiation of ship propulsion by steam as if these were matters "discovered" or "invented" by an individual or individuals of a certain country and period. Steam navigation, as has been shown, was not a discovery, nor the inspired idea of one ingenious mind, of one country, or of one period of time. It was an obvious complement of already existing things, and a problem long appealing for solution to many minds in common in different countries, and its solution at last was not the work of one individual, nor the arena of that solution any one particular district or country. All associated or engaged in the solution were working on the strength of steps in advance already accomplished, and about which they could scarcely have been entirely ignorant. But to elaborate the story of the introduction and development of steam navigation, and the wonderful revolutions which progress in it has effected in human affairs and in the character and position of nations, is quite needless in this work. These are matters which have been told almost to weariness by numberless pens, and in what follows the history of navigation and of the growth of shipping will only be treated just as it may be necessary to the more adequate elucidation of our subject proper, viz. the art, science, and industry of shipbuilding.

The first practically successful steamer on any serviceable scale was the *Charlotte Dundas*, built at the eastern terminus of the Forth and Clyde Canal in 1801–2. This vessel was due to the enterprise of Lord Dundas (then a governor of this canal) and the

genius of William Symington, already mentioned. She was launched in 1802, and in March of that year she towed on the canal, against a head wind, two loaded sloops of seventy tons burden each, accomplishing 19½ miles in six hours. Driven by a Watt double-acting engine turning a crank on the shaft of the paddle-wheel, which was situated at the stern, the speed obtained, when not towing, reached six miles per hour, and the only objection to the continuous employment of this—the pioneer steamboat in useful service—was a fear, on the part of the canal proprietors, that the disturbance of the water by the paddle-wheel would seriously injure the banks. Lord Dundas having laid the matter before the Duke of Bridgewater, the latter gave Symington an order for eight boats like the *Charlotte Dundas* to be used on his canals. The death of the Duke soon after, however, prevented the contract being carried out. Symington gave up in despair, his chief, if not only, reward being a grant, first of £100 and later of £50, from the British Government in acknowledgment of his services.

Fulton, of America, already mentioned, was in this country, and inspected the *Charlotte Dundas* with Symington; and so, it may also be mentioned, did Henry Bell of *Comet* fame, who from at least 1800 had deeply interested himself in steam navigation, and continued all along to experiment with boats and engines and to advocate the principle with our own and other governments; Fulton himself being one of his correspondents. The American (whose father, by the way, is said to have gone to America

from Ayrshire) no doubt saw that if the destruction of Scottish canal banks was the only obstacle in the way of navigation by steam he need have no fear for the success of the system on the great natural waterways of America. In the spring of 1807 (or five years before the launch of Bell's *Comet*) there was launched from the shipyard of Charles Brown, on the East River, New York, to the order of Robert Fulton, the steamer *Clermont*. The hull of this boat was 133 feet long, 18 feet wide, and 9 feet deep, and she was fitted with a steam engine having a cylinder of 24 inches diameter and 4 feet length of piston stroke. This engine was made by Boulton and Watt at Soho, Birmingham (from, it is said, data supplied by Fulton), and forwarded to America. In the autumn of 1807 the *Clermont* made a trip to Albany, running the distance of 150 miles in thirty-two hours steaming time, and returning in thirty hours. This was undoubtedly the first voyage of any considerable length made by a steam vessel which continued in permanent service, and Fulton, however much he may have been indebted to his predecessors in America, or however much he may have gleaned from his correspondence with and visits to Symington, Bell, and others in this country, is yet entitled to the honour of having been the first to apply the steam engine to ship propulsion, and to make steam navigation an established everyday commercial success.

The *Clermont* was at once employed in passenger service between New York and Albany, and in 1808 she was repaired and enlarged. Two new steamers, meanwhile—the *Raritan* and the *Car of Neptune*—

had been built by Fulton, and in 1811 he built the *Paragon*, a vessel of nearly double the size of the *Clermont*, and three times the size of Bell's *Comet*, just then building in the yard of John Wood, at Port Glasgow, the engine for which, of 3 horse-power, was jointly being prepared by Bell, who was a millwright by calling, and was proprietor of the Baths Hotel at Helensburgh, opposite Greenock; by David Napier, who supplied the engine-castings, boiler, etc.; and by John Robertson, of Glasgow, who advised upon and erected it in the vessel.

Bell's *Comet*, 40 feet long (afterwards lengthened), and 10½ feet beam, and at first fitted with two systems of "malt-shovel" propellers on each side, which drove her at five miles an hour (afterwards attaining six miles an hour, with one paddle-wheel of a more modern pattern on each side), was running on the Clyde in August, 1812, and was undoubtedly the first steam vessel employed in Europe in regular passenger service, and the first there effectively to demonstrate steam navigation to be an everyday commercial success. Following the *Comet*, John Wood was commissioned to build the *Clyde* and the *Elizabeth* for Glasgow owners. The latter was launched in March, 1813, and marked a considerable advance upon Bell's, her dimensions being 58 feet over all, 51 feet keel, 12 feet beam, and 5 feet depth of hold. She measured 33 tons burden, and was driven by a 10 horse-power engine, her speed, it is averred, being nine miles, as against the improved *Comet's* six miles per hour.

The Clyde steam shipbuilding industry, almost from the advent of Bell's little vessel, was fairly

inaugurated, and the rapidity of production within the succeeding ten years was quite remarkable, considering the diffidence that generally marked the adoption of mechanical innovations during the first twenty years of the last century. In 1813 four steamers had been built, and in 1814 double this number were added. In 1815 six were added, in 1816 six more, and so on till 1822, when no fewer than forty-eight steamers had been finished on the banks of the Clyde. Of the eight steamers built during 1814 two are worthy of special mention. One, the *Industry*, built by Fife of Fairlie, was still extant in 1890, and was an object of interest as exemplifying the "cod head and mackerel tail" form of hull then in favour. Her engines are still preserved, with other even earlier examples of marine engineering, in the Glasgow Museum. Another vessel of that year was the *Marjory*, built by William Denny, father of the founders of the present firm of William Denny and Bros., Dumbarton. She was the first steamer to ply upon the Thames, having been bought by a company of London merchants, and taken thence soon after her launch. The early steamers on the Clyde only plied to ports on the river or the estuary, such as Largs and Rothesay; but in June, 1815, the *Britannia*, the largest steamer of the time, made a trip to Campbeltown, and was subsequently put on the route between Glasgow and Londonderry, thereby opening up trade with the latter port. She was 109 tons burden, and measured about 93 feet long by 16½ feet beam; her engines, of the beam type, with spur-wheels to raise the power to the paddle-shaft, being of 32 horse-

power. In 1814 three steamers were built, to the order of John Robertson, at Dundee, the engines for which he supplied. Two of these, the *Caledonia* and the *Humber*, were sent under steam to the river Humber, and plied there, these probably being the first steamers sent from Scotland to England.*

With the year 1818, steamship building on the Clyde received a fresh impetus from the energetic genius of David Napier, who thoroughly grasped the possibilities of steam navigation in connection with coasting and oversea traffic. In that year he negotiated with William Denny for the construction of a steamer, in which he proposed fitting one of his engines of 30 horse-power. Previous to the vessel being proceeded with, he experimented with small models in a canal near his works at Camlachie, and as a consequence, determined to give his proposed steamer a sharper entrance at the bow than was at that time common in river steamers. The vessel resulting from this forethought was the *Rob Roy*, of ninety tons, which had the distinction of being the pioneer steamer to engage in channel service. She was the first to carry on a regular steam service between Greenock and Belfast, and being afterwards transferred under the name of the *Duc d' Orleans*, she ran successfully as a passenger ship between Calais and Dover. Other larger and more powerful vessels, built by different Clyde firms, and engined by David Napier, and by his cousin Robert, rapidly

* For a thoroughly interesting and complete account of Clyde steamers, early and modern, see *The Clyde Passenger Steamer*, by Captain James Williamson (McLehose, 1904).

followed for service on various routes, *e.g.* Glasgow and Liverpool, Holyhead and Dublin, Leith and London; and in 1826 Steel and Co., Greenock, built for the latter the *United Kingdom*, which for size was the wonder of the times. She was 160 feet long, 26½ feet beam, and had engines by David Napier of 200 horse-power; her paddles, however, being supplemented by a heavy rig of sails.

Steamship building and propulsion in America, having had the start of Britain by at least five years, underwent even more rapid development. The *Clermont*, launched in 1807, as has been noted, was over three times longer and five times the tonnage of the *Comet*, launched five years later. Before one single steamboat had been built elsewhere than in America, Fulton already had six built there, and in the autumn of 1814 there was launched, from his design, the war steamer *Demologos*, or *Fulton the First*, a double-hulled vessel, 150 feet in length, 56 feet in breadth, and 20 feet deep, with a tonnage of 2,475 tons. Claimed as the pioneer war steamer, she was certainly, for the time, a most remarkable production, and in the matter of tonnage was ahead of anything until 1838. Canada did not lag much behind America in the introduction of steamboats on her inland waters, for the steamer *Accommodation* was placed on the St. Lawrence in 1809, and the *Car of Commerce* in 1813. In 1817 two other steamers were placed on the St. Lawrence, the *Quebec* of 100 tons burden and 100 indicated horse-power, the engines for which were supplied by Maudslay, London, and also the *Lauzon*, ferry steamboat, 150 tons

measurement and 50 horse-power. Canada, too, has the honour of having ushered into the arena of Atlantic navigation the first Atlantic steamer, *The Royal William* (with engines by Boulton and Watt), which crossed from Quebec to London, in the autumn of 1833, in seventeen days steaming throughout.

The Atlantic service is usually selected as affording the most notable and connected epitome of the later development of ocean navigation by steamships, and the same plan is here adopted.

Apart from some earlier voyages of an experimental or tentative character—for example, the American-owned *Savannah*, in 1819, which only used steam as an auxiliary to sails, and the Canadian-owned and built *Royal William*, in 1833, above referred to—our brief record may be begun with the epoch-marking passages of the *Great Western* and the *Sirius*, in the spring of 1838. Under the inspiring influence of the intrepid genius of Isambard K. Brunel, the engineer for the Great Western Railway, the directors of that company had, in 1836, formed the Great Western Steamship Company, the firstfruits of which consisted in the building of the paddle steamer *Great Western*. This vessel, whose launch took place at Bristol on July 19th, 1837, was 212 feet long between perpendiculars (236 feet over all), 35¼ feet beam, and 23 ft. 2 in. depth of hold. Her engines by Maudslay and Field, who had been for some time one of the most notable marine engineering firms in Britain, as their successors still are, were of 750 indicated horse-power. She was despatched on her first voyage across the Atlantic from the port of Bristol, on April

8th, 1838. Three days previously, however, the paddle steamer *Sirius*, 170 feet long, 450 tons register, and 270 horse-power (built 1837–8 by Menzies and Son, Leith, and engined by Thomas Wingate and Company, Glasgow, and the first steamer to be fitted with Hall's surface condenser), left Cork Harbour—where she had touched on her way from London, and which had formed her terminal port previously—also bound for New York. The story of the arrival of both the vessels at New York on the same day—the *Sirius* in the forenoon with all her fuel consumed, and the *Great Western* in the afternoon, with nearly 200 of her original 800 tons of coal still to spare (the time thus taken being eighteen days and fifteen days respectively), and the furore of excitement their almost "neck-and-neck" arrival occasioned, as well as the gratifying success of their homeward passages, etc.—need not be dwelt upon. These momentous events at once established the practicability of steam navigation over long distances, and virtually reduced the breadth of the Atlantic by one-half. While the possibility of ocean transport by steam vessels was thus being signally demonstrated—a matter which had been doubted, on the score of limited coal-carrying capacity, even by very learned men—the genius of Brunel was measuring itself against a further leap along the same line of development. The *Great Britain* was being laid down in the yard at Bristol.

At this point in the narrative of Atlantic steamship development, it will be convenient to pause, and to go back a little in the order of time, so that the initiation and gradual adoption of iron as the con-

structional material for ships may be adequately dealt with. Until about the years 1783–4 when Cort introduced his patent processes for puddling and rolling iron, hammering was the only process by which wrought-iron could be shaped from the rough mass into plates and bars, hence, even for structures on land, the material was but little used. According to Sir William Fairbairn, "when Watt was engaged with his steam engine the only material at his command for his boiler, in which to generate steam, was hammered copper plates or cast-iron: hammered iron plates were occasionally made, but seldom used, and it was not until the introduction of rolls that anything in the shape of iron plates could be obtained." Rolled iron plates were first extensively used in the construction of steam boilers, the earliest of these being produced about 1786. In 1787 John Wilkinson, an ironfounder of Lancashire, launched the *Trial*, a canal boat or barge, of 70 feet length, built of iron plates $\frac{5}{16}$ inch thick, "put together with rivets like copper or fire engine boilers," this being the first iron vessel of which any account is extant. She had wooden stem, sternpost and beams. When this novel craft arrived at Birmingham with a cargo of about twenty-three tons of iron—her own weight being eight tons—probably none of those who witnessed her arrival had any idea of regarding her as the pioneer of a new system of construction that was to extend to all classes of ships, and revolutionise the art of shipbuilding. Yet so it was; although the change did not begin to manifest itself in the localities where it eventually developed most for thirty years later;

the *Trial* was the forerunner of many similar craft which plied on the Severn and the canals of Staffordshire; their facility of construction, strength, lightness, and efficiency commending them. The construction and use of similar vessels in other parts of the country followed, while the idea of building vessels of iron for river and sea-going purposes was entertained and expressly advocated by various individuals in different places simultaneously. Thus Richard Trevithick in 1809, and Robert Stephenson later, proposed iron vessels, and even suggested masts, yards and spars of iron plates, anticipating by many years the almost universal practice of the present time.

The Clyde Valley, for so long subsequently recognised as the "home of iron shipbuilding," was longer in becoming associated with the introduction of metallic shipbuilding, but when once started its share in the movement was pronounced and progressive. The pioneer iron vessel in this region was the *Vulcan*, built at Faskine, on the Monkland Canal, in 1817–8. Equipped as a "passage boat," this was probably the first iron vessel regularly employed in passenger carrying. The builder was Thomas Wilson, a carpenter in the employ of the Forth and Clyde Canal Company, who undertook her construction for it. This vessel was 61 feet long, 11 feet beam, and 4 ft. 6 in. deep, and was built of plates and flat bar frames, the framing and stanchions being forged wholly on the anvil by hand labour. While engaged in its construction, Wilson and his blacksmith assistant were frequently jeered at by sceptical fellow-workmen and passing bargemen. To the

derisive query as to whether he really imagined that iron would "soom" (float), Wilson merely retorted to the effect that they could judge for themselves if they "pitched their tea flasks into the canal." Heedless for most part of those jeers and scoffers, Wilson, like Noah of old, went steadily on with his shipbuilding. The *Vulcan* was not only safely floated, but commenced plying on the Forth and Clyde Canal in 1819, and was to the fore so recently as somewhere in the seventies, having actually stood the test of between sixty and seventy years' hard service!

By the time the *Vulcan* had begun to ply on the canal—the mode of progression being, of course, horse haulage—the propulsion of boats by steam had become firmly established on the Clyde and other rivers, while also about that time the *Rob Roy* began to ply across Channel to Belfast. But all the steamers turned out up till then were of wood, the employment of the steam engine for propulsion apparently constituting an innovation so all-engrossing as to preclude for a time any serious effort to bring about the substitution of iron for wood in their construction. The first iron steamer, of which there is authentic record, was the *Aaron Manby*, built in 1820, not at any seaport, but at the Horsley Iron Works, Tipton, Staffordshire. Quite evidently iron was then regarded with anything but favour by the shipwrights and builders of our seaports, as indeed it was also much later regarded by shipwrights in our Royal Dockyards, whose training and precedents excluded all other materials but wood. Named after her designer and constructor, the *Aaron Manby* was 120 feet long and

18 feet broad, with engines of 80 horse-power. She was sent in pieces to the Thames, and put together at the Surrey Docks. With a cargo of iron and linseed she crossed the Channel to Havre in 1821, and afterwards ascended the Seine to Paris, where her arrival caused a great sensation. Her success led to the construction of other iron steamers, both at Horsley Works and at Mr. Manby's works at Charenton, near Paris; one of the Horsley productions crossing the Irish Channel and taking up service in 1825 on the river Shannon, in which she continued for the long period of thirty years. The first Clyde-built iron steamer was the *Aglaia*, of thirty tons burthen, produced in 1832, and re-erected by the side of Loch Eck, Argyleshire, on whose waters she afterwards plied; but the first iron steamer to ply regularly on the Clyde itself was the *Fairy Queen*, built in 1831 by Neilson, of Oakbank Foundry, in the northern district of Glasgow. The hull was constructed there, and carted down and launched into the Clyde at the Broomielaw. One who, as a boy, watched her construction, states that "the hull all over was rivetted as boilers were, the rivet heads projecting, not countersunk as the practice now is." The first iron steamer built on the Tyne was the *Prince Albert*, 155 feet long, 19½ feet beam, and 9 ft. 6 in. deep, launched in September, 1842, and intended for passenger service on the Thames.

No inconsiderable share of the credit attaching to the substitution of iron for wood in shipbuilding and for the development of the steamship is due to William and John Laird, father and son, founders

about 1824–6 of the renowned firm of shipbuilders at Birkenhead. In 1829 they built an iron lighter 60 feet long, the first iron vessel constructed on the Mersey, and during the succeeding three years a number of iron vessels for exploration purposes on the Niger. One of these, the *Elburkah*, was 70 feet long, 13 feet beam, and 6½ feet deep. Her plates were ¼ inch thick on the bottom and ⅛ thick on the sides, and she weighed only fifteen tons, including her decks, but without engines, boilers, spars, and outfit. In 1833 they constructed a paddle steamer, the *Lady Lansdowne*, 133 feet long and 148 tons, which was sent from Birkenhead in pieces, and re-erected on the banks of Loch Derg, in Ireland. In the following year they constructed two paddle steamers—one the *Garryowen*, 130 feet long, by 21½ feet beam, and of 265 tons, having two engines of 45 horse-power, for the Irish coasting trade; and the second, the *John Randolph*, shipped in pieces to, and re-erected on the Savannah River, U.S., being the first iron vessel ever seen in American waters.

The phenomenon, as at first it seemed, of the iron ship "sooming," or floating, soon ceased to excite distrust, although opposition to iron ships on the score of the ease and rapidity with which, as was averred, they would sink in the event of collision, and on account of their readiness to foul and corrode, as well as of their magnetic influence with the compass, long deterred owners from using the new material. This was still the state of matters in 1838, when, after the epoch-marking Atlantic voyage of the steamer *Great Western*, Brunel advised the

Great Western Company to use iron in the construction of a new steamer for ocean service which was to be of the startling size of 3,433 tons displacement. This, of course, was the *Great Britain*, already incidentally referred to. Other men and companies, although perhaps not quite so boldly, were also entering upon shipbuilding in iron. In 1838, the year in which Brunel proposed his *Great Britain*, the firm of Tod and McGregor, Glasgow, was actually proceeding with a vessel of iron intended for deep-sea service. This was the *Royal Sovereign*, launched in 1839, and put on the service between Glasgow and Liverpool. She was followed shortly by the *Royal George* and the *Princess Royal* by the same builders. In 1838, also, Mr. John Laird produced the *Rainbow*, an iron steamer of 600 tons, for the General Steam Navigation Company of London. She was employed in the service between London and Ramsgate, afterwards extended from London to Antwerp. These several Clyde- and Mersey-built vessels may be considered the pioneer iron ocean steamers.

It was in 1830 that Mr.—afterwards Sir—William Fairbairn first turned his attention to the construction of iron vessels, in connection especially with the design of canal boats of greater speed than existing craft, as a result of the competition even then being encountered from railways. A number of these vessels were built at Manchester to the order of the Forth and Clyde Canal Company, and made the passage from Liverpool to Greenock prior to entering on service in the canal. The most successful or best known of these was the *Lord Dundas*, completed in

1831, which was 68 feet long, 11½ feet beam, by 4½ feet depth, with a shell formed of iron sheets $\frac{1}{16}$ inch thick, strengthened with light angle and T-iron ribs. An engine of the locomotive type, about 10 horse-power, drove a paddle-wheel of 9 feet diameter and 3 ft. 10 in. width, placed a little aft of midships and worked in a channel-recess formed in the hull to allow of the flow of water to the paddles. The success of this vessel, conjoined to his other experience of building in iron, induced Fairbairn to begin iron shipbuilding on a larger scale. In 1833 he established a yard at Millwall on the Thames (which afterwards formed a part of the works in which Scott Russell constructed Brunel's *Great Eastern*), where in the course of some fourteen years he built upwards of 120 iron ships, some of them over 2,000 tons burden. Though not remaining personally engaged in shipbuilding, Fairbairn continued to the last to watch and aid its development. Combining as he did the professions of civil engineer and shipbuilder, he made his experience in the one contribute to success in the practice of the other, and his experimental investigations and their resulting suggestions largely contributed to the advancement of metallic shipbuilding. Partly because of his acquaintance with iron as a material for shipbuilding and of his possession of special plant, Fairbairn was entrusted by Robert Stephenson with the experiments which preceded the construction of the Britannia Tubular Bridge across the Menai Straits, and it was from these experiments, and their outcome in practice, as embodied in this and other bridge structures, that

some of the most valuable principles underlying iron construction were derived. For example, the comparison of a ship to a girder, which has almost ever since been the governing principle on which questions of structural strength have been determined by naval architects, originated with Fairbairn, although Brunel in his design of the structures of the *Great Western*, *Great Britain*, and *Great Eastern* undoubtedly worked on the same lines. The credit, however, of putting into final and workable shape "equivalent girder" calculations for the longitudinal strength of ships was earned later by Macquorn Rankine, the able Professor of Engineering in Glasgow University.

The cellular principle of ship construction, as exemplified in the bottoms of almost all modern ships, is in the same way a direct deduction from wrought-iron bridge construction, and from the notable vessels in which it was first embodied—the *Great Britain* and *Great Eastern*. The misfortune which overtook the *Great Britain* on her third voyage, as afterwards related, helped incalculably to develop shipbuilding in iron. The vessel, after lying aground in no very comfortable situation for about eleven months, was floated, and on a general survey being made it was found that she had not suffered any alteration in form, nor was she at all strained. Many of the shipbuilders and shipowners who had been hesitating about the judiciousness of employing iron, paid visits to the stranded vessel, inspected her after docking, and felt entirely convinced of the suitability of iron for ship construction.

From what has gone before it will be gathered that civil engineers, ironfounders, and others outside the regular—and shall we say "sacred"?—pale of the shipwright craft contributed most to the early stages of shipbuilding in iron. At this point we may fittingly refer to the position and influence of a society which had, many years before, become most potent as a factor in shipbuilding development, and is even to-day quite as powerful as ever. This is Lloyd's Register of Shipping, representing a power of which, behind the well-known expression "100 A1 at Lloyd's," most people have, at least, some general idea. Although as a register society for the classification of vessels, to aid in their insurance, this body carries one back through varied intricate, and more or less permanent, successions of insurance lists, records, and register-books, to the time, 1690–1770, when Lloyd's Coffee-house in Lombard Street, London, was the great resort of all classes of people connected with shipping—gradually developing into the headquarters of maritime business, and especially of marine insurance—it was only in 1836 that the association, known since that date as "Lloyd's Register of British and Foreign Shipping," was formed. It was, moreover, only in 1837 that the Register-book, kept and issued by the association, took cognisance of shipbuilding in iron, the steamer *Sirius*, of 180 tons, in that year being the first vessel in which iron was largely employed to receive countenance or class from this already influential and, of course, conservative association. She appeared in the supplement to the 1837 volume, having the "A" character without a term of years, and

the notation "built of iron." The next entered in the book was the iron sailing-ship *Ironside* of 270 tons, built in 1838, and from that year till 1844 the Register-book continued to take cognisance of the new style of construction in no other way than that each vessel was "built of iron." In the latter year, recognising that iron ships had so multiplied as to demand some kind of higher class based on fixed rules, the Register Committee appealed to the shipbuilders of the country for assistance in compiling such rules. The request, however, as we are told in the *Annals of Lloyd's Register*—a highly interesting work issued to its subscribers by Lloyd's Register Society in 1884—was made in vain, and the iron rules remained in a vague and indeterminate form until the year 1854. The committee hesitated to lay down hard-and-fast lines for the construction of iron ships while such ships were in their infancy, preferring rather to await more lengthened experience. It might have been more correct to say that the committee—with the shipowning and insuring interests predominating—could do nothing else than await on experience. During these early stages of iron shipbuilding, down indeed to comparatively recent times, the reward of individual superiority, in improving shipbuilding practice and methods generally, assumed the form of enhanced reputation as builders and consequently of extra inflow of orders to build for new and more important customers. At first especially, but indeed all along, Lloyd's and other succeeding registration societies, almost as a necessity of their existence, have availed themselves, through the agency of their constantly

growing staff of surveyors, etc., of the results attained by the special skill and experience of progressive shipbuilding firms and individuals, to formulate, build up, and issue rules and regulations, which although almost needless in the case of skilful, honest, and progressive builders and designers, yet guide and compel the conventional and laggard builders along the line of improvement. Of course, while the general level of quality is thus maintained, and the *raison d'être* of the registry societies—*i.e.* the guarantee afforded to insurance bodies—justified, the reward of skill to individuals is lessened. Progressive and ingenious shipbuilders quite naturally desire that the advantages due to their own suggestions and devices should first—if not first and last—accrue to themselves, and it is easy therefore to understand that the early function of Lloyd's was one of "registering" rather than of initiating and improving practice.

But shipbuilding interests and skill are now greater powers in the formation and conduct of register societies, and more general scientific as well as practical skill are necessary qualifications for the members of the surveying staffs. Indeed, in particular instances the officials of Lloyd's and other later registry societies have evinced great technical initiative ability. It is not possible here to write more fully of registry history and procedure, and we must content ourselves with mention of the Liverpool "Underwriters' Registry for Iron Vessels," founded in 1862, and absorbed by Lloyd's in 1885; the Bureau Veritas, a French society of old standing, and having great influence with continental owners

and insurance societies; and the British Corporation Registry founded in 1890, and since that date a rapidly flourishing institution, which, like the others named, has shown the lead in a number of important departures, both in general type and structural details of ships, to the old and more widely ramified, though more conservative, Lloyd's Society.

Greater strength-with-lightness and the vastly superior manipulative and constructural character of iron are, of course, the primary advantages of that material over wood. On these points it is at this day unnecessary to dwell, but a sentence with regard to increased strength-with-lightness may not be amiss. Of two vessels, one of wood and one of iron, having the same outside form and draught of water, the iron vessel carries by far the greater weight of cargo. From experience it was learned that to give sufficient strength to a wooden hull it was necessary to make it nearly as heavy as the burden it had to carry, whereas a hull of iron, and even more so of steel—the latter material being still lighter than iron relatively to thickness and strength—often carries cargoes twice its own weight without showing the least sign of weakness; the superior way in which iron lends itself to butt-fastening no doubt contributing to this result. The gain in favour of the carrying power of iron ships is consequently one-sixth at least of the total weight of a ship and her lading. The commercial gain of this alone, both at first and in a vessel's after life, forms overwhelming advantage for the metallic hull, quite apart from the marvellous way in which metal lends itself to manipulation and to enlarged ship dimensions.

Even after these, now almost obvious, truths were more or less clearly recognised, transition was slower on account of the familiarity and expertness of the ship-carpenter with woodwork. The antipathy of the old-time "shipwright" to the new order of things lasted long. Even the Chief Constructor of one of the Royal Dockyards declared to Scott Russell, with such feeling and indignation that the latter says he never forgot it, "Don't talk to me about ships of iron, it is contrary to nature." One disadvantage, however, already mentioned, which iron indisputably had—and both iron and steel ships still to some extent have—also hindered the spread of shipbuilding in metal. Experience showed that the bottoms of iron vessels were subject to fouling and corrosion, especially in certain waters and if long afloat and stationary. The speed in such cases became greatly reduced, and deterioration in the metal also became serious. Coppering the bottoms of wood ships was a more or less effective specific against fouling, but as it was impracticable, as well as chemically undesirable, to affix copper sheathing to iron, wood for this reason alone was retained as the material for the outside skin of ships. In many cases wood sheathing was fitted to an iron inner skin so as to afford the means of affixing copper and preventing galvanic action between it and the iron. Indeed, in not a few of even the latest naval ships—especially those intended for stations and service in Eastern waters—the combined wood and copper sheathing has been perpetuated. But in many instances iron plating was altogether dispensed with, and wood planking

wrought upon the iron frames, such vessels coming to be spoken of as "composite" vessels from the association of wood and iron in their construction, although it will be understood wood and iron (wood frames and iron plating) had been combined from a much earlier period. The planking of these vessels was, of course, caulked along the seams, and the whole clad with copper sheathing as in the case of ordinary wood ships, thus giving them the advantages of cleanliness and consequent speed.

The composite system was well adapted for the ships which at that period were in demand for the trade with China and the East Indies round the Cape of Good Hope; speed on the homeward passage being a great desideratum. The composite "tea clippers" and their astonishingly swift ocean voyages *viâ* the Cape, with cargoes of the season's teas, are generally memorable. The first vessel of this composite class of which there is reliable record was the *Tubal Cain*, of 787 tons, built about 1850. This vessel appeared in Lloyd's Register for 1851 with the notation "Iron frame planked" and with the character "A," but with the period of classification unstated, due, doubtless, to the want of data as to the durability of vessels thus constructed. In 1860, and the years immediately following, proposals for composite vessels increased in the experience of Lloyd's Register, one notable advocate of this type of vessel being the late Alexander Stephen, one of the founders of the present renowned firm of Alexander Stephen and Sons, Linthouse, Glasgow, who, in 1862, was the first to introduce the composite system on the Clyde and

to place it before the Admiralty. Amongst the most famous of the composite tea clippers of 1860–70, were the *Tæping*, *Ariel*, *Titania*, *Spindrift*, *Sir Lancelot*, and *Thermopylæ*. The latter vessel was designed by the late Mr. Bernard Weymouth, of Lloyd's Register, who was largely responsible for the rules of the society for composite vessels. She was built in 1868 by W. Hood and Co., Aberdeen, and for a number of years accomplished many marvellously quick passages between this country, Australia, and China. One of her performances consisted in making the passage from London to Melbourne, in 1870, in sixty-one days, during one of which she covered a distance of 330 nautical—about 380 statute—miles, or at the average rate of close upon sixteen statute miles per hour.

Owing to galvanic action, the character of the bolt fastenings of composite vessels was a matter of first importance, and difficulties in this connection largely determined the period of their classification, the frequency of the survey, and ultimately the duration of the day of composite construction. When the Suez Canal was opened and first regularly made use of in 1870, the qualities of the fine clipper tea-ships were discounted. This change shortened the route for steamers to the East, and the compound engine, coming into general use about the same time, effected a great economy in coal consumption. Compared with iron ships, too, the construction of composite ships was found to be somewhat expensive, and this of itself hastened the decline in their production. Nevertheless, up to the present day practically all the

large sailing yachts, including the most famous racing boats, have been built on this principle, with one or two exceptions, notably the America Cup challengers *Shamrock I.* and *Shamrock II.*, which were constructed of bronze alloys, and the *Shamrock III.*, which was built of nickel-steel, afterwards to be referred to.

Like wood shipbuilding in this country, composite shipbuilding has virtually now only historical interest. So leaving the subject finally, we again take up the main line along which shipbuilding has proceeded, as exemplified particularly in transatlantic vessels. Some three or four years before the completion of the *Great Britain* the founding of the Cunard Company had been brought about, and Atlantic vessels were multiplying. That memorable event, as is well known, took place in 1840, and through it a regular mail steam service was first introduced on the Atlantic. The *Britannia*, built by Robert Duncan, Port Glasgow, was the first vessel of the fleet, and measured 207 feet in length by 34 ft. 4 in. broad, by 22 ft. 6 in. deep, with a tonnage of 1,154, and an I. H. P. of 740, yielding 8½ knots average speed. Closely following her were the *Acadia*, *Caledonia*, and *Columbia* of same dimensions, all engined by Robert Napier, Glasgow; the story of whose association with Cunard and McIver, and the founding of the Cunard Line, has been too often told to bear even the briefest repetition.

The *Great Britain*, begun in 1838, but not completed until 1844, and only leaving Liverpool on her first voyage in July, 1845, was the marvel of her day,

and in herself represented a striking exemplification, not only of growth in steamship dimensions, but of the revolution in construction and propulsion, destined before many years to completely supplant the wood hull and paddle-wheel for ocean service. In length this remarkable vessel was 325 feet over all, by 50½ feet beam, and 32½ feet deep, with a displacement at load draught of 3,610 tons. She was not only built of iron, but fitted with a screw propeller, the application of which Brunel had already studied in the case of the *Archimedes*, just about that time, earning the distinction of being the first practically successful screw-propelled steamer. In fact the determination to employ the screw in place of paddles in the *Great Britain* was resolved upon in 1839, after the engines designed for paddle-wheels had already been under way.

The idea of employing the principle of the screw for ship-propulsion is known to have been entertained from a period almost as early as the application of steam as the motive power. There have been many claimants to priority in this matter, and the subject is so beset with intricate and conflicting claims and counter-claims that it would be futile to attempt a satisfactory statement here. Among the first to score decisive success, and to convince the engineering profession of the practicability of screw-propulsion, were John Ericsson and Thomas Pettit Smith. The former in 1836, with the *Francis B. Ogden*, obtained success on the Thames, and the latter in 1839, with the above-mentioned *Archimedes*—a vessel of much larger size—clearly demonstrated the practicability

and value of screw-propulsion. The innovation in the case of the *Great Britain* was a distinct success, and her first voyage across the Atlantic to New York occupied fourteen days twenty-one hours, while the return voyage occupied fifteen and a half days. After one more voyage she was fitted with a new propeller, and alterations were made to give a better supply of steam. She made two more voyages, but on her third voyage, from Liverpool (September, 1846) she overran her reckoning and stranded in Dundrum Bay, in the north-east of Ireland. This mishap, though rectified, completed the ruin of the Great Western Company, already sorely crippled in finance through the establishment of the subsidised Cunard Line.

Of the American Collins Line's rivalry of the Cunard Company, which started in 1850, as well as of the establishment in 1850 of the Inman Line, in 1856 of the Anchor and the Allan Lines, in 1863 of the Guion Line, and in 1870 of the White Star Line, not much need here be said. These are matters for fuller treatment, more appropriate to the companion volume on Shipping. The vessels brought into existence by these rival companies exemplified the progressive spirit which then had possession of owners and builders of ocean steamships—a spirit which received lasting impetus from the change from wood to iron construction and from paddle-wheel to screw-propulsion.

While the Collins Line assailed the Cunard service with vessels of American build, exceeding in size and speed anything then afloat, these, as we have seen, were still of wood construction, and were

paddle-propelled; but it was with iron screw-propelled steamers—the *City of Glasgow* and the *City of Manchester*, 1,680 tons and 350 horse-power—that the Inman Company boldly entered the arena in 1850. When the Cunard Company realised the formidable competition they were being met with, they made renewed and extraordinary exertions to retain their position. They sent forth the P.S. *Arabia*, of 2,400 tons and 938 horse-power, in 1852, and in 1855 the P.S. *Persia*, the first iron vessel they owned and the largest and swiftest of the fleet. In 1862 they placed the P.S. *Scotia* on the Atlantic; built like the *Persia*, of iron, but of greater dimensions and superior in speed and strength to that vessel. She measured 366 feet in length, 47½ feet beam, 30½ feet deep, her gross tonnage being 3,871. Her engines were of 975 nominal horse-power, but she indicated at sea as much as 4,200 horse-power. Her two cylinders were respectively 100 and 144 inches diameter, and her paddle-wheels upwards of 40 feet diameter. Notwithstanding that this vessel was glowingly referred to at the time as "the champion and model of a mercantile ocean steamship," and that her early performances surpassed those of any previous vessel, she was destined to be the last of the paddle steamers built by the Cunard Company. In the same year which gave her birth, the Government sanctioned the use of the screw in the mail steamers of the Cunard Company, and the screw steamer *China* was at once the result. This vessel was followed during the next two years by four others, the result of whose performances clearly

demonstrated—if demonstration were needed—that the screw steamer, in point of efficiency and economy —especially with the improvement which had concurrently taken place in the marine engine—far surpassed the paddle steamer for deep-sea traffic. Reasons need scarcely be adduced for this, but it may be mentioned that, situated as it is at the stern of the vessel, and fully immersed, the screw acts upon relatively a much larger volume of water in a given time than paddle-wheels, and its efficiency is not impaired by the rolling and pitching motions of the vessel, or completely nullified by variations in the ship's draught of water, as with paddles. Development in size and power now proceeded more swiftly than ever, but the lines on which it moved were conventional and more in sequence with what had gone before. Steam navigation itself grew and flourished amazingly, additional companies being formed and new steamships produced with such rapidity, and for services having such widespread ramifications, that it would be quite futile, even if necessary, to attempt here any adequate survey of the movement. The later stages of steamship development, as represented mainly by transatlantic liners, will be referred to in the following chapters, as will also, briefly, those outstanding concurrent improvements in marine engines and propulsion without which development in size and power could not have proceeded as it has done.

CHAPTER II

DEVELOPMENT OF THE MODERN STEAMSHIP

COMMERCIALLY, as is well known, the *Great Eastern*—"Brunel's great audacity," as she has been called—all along proved a lamentable failure, although at various times in her long life she achieved most useful service in submarine cable-laying—service, indeed, which but for her could not well have been accomplished. From the time of her construction, however, down to her ultimate breaking-up on the Mersey in 1890, she stood out unapproached as a wonder and pattern of naval construction, and furnished in great measure the experience on which later designers and constructors have based their productions. In her admirably conceived and splendidly wrought structural arrangements—due to the joint skill of Brunel and Scott Russell—she exhibited as successful an embodiment of the dual quality of "strength with lightness" as can be found in any subsequent ocean-going merchant ship. She was, if not the first, certainly the greatest exemplar of the longitudinal system of construction, and in virtue of this, conjoined to her phenomenal dimensions, she formed an inestimable source of inspiration to ship-

builders and owners in their ventures on increased dimensions, although to shipowners alone she has been in a commercial sense somewhat of a beacon of warning.

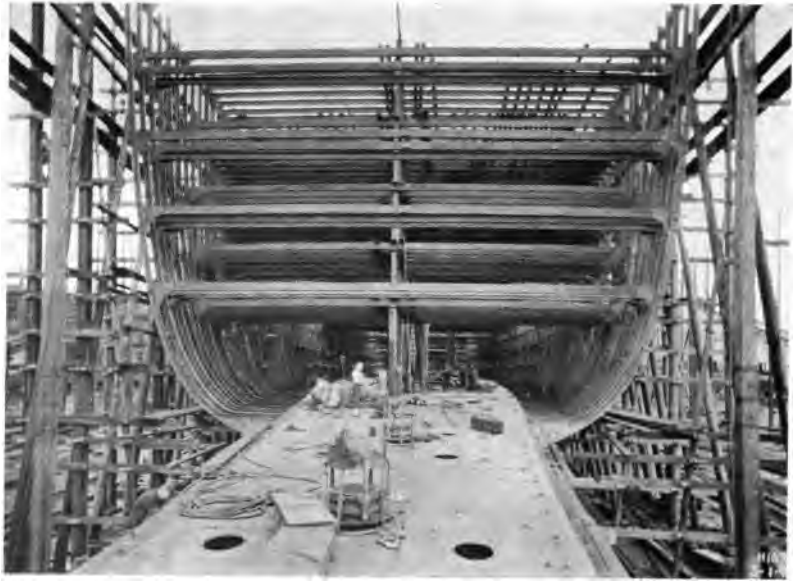
Speaking of Brunel and his great achievement, Sir William H. White, the late Chief Constructor of the British Navy, in his elaborate and most informing address of November, 1903, as President of the Institution of Civil Engineers, says: "Having recently gone again most carefully through Brunel's notes and reports, my admiration for the remarkable grasp and foresight therein displayed has been greatly increased. In regard to the provision of ample structural strength with a minimum of weight; the increase of safety by water-tight subdivision and cellular double-bottom; the design of propelling machinery and boilers, with a view to economy of coal and great endurance for long-distance steaming; the selection of forms and dimensions likely to minimise resistance and favour good behaviour at sea; and to other features of the design which need not be specified, Brunel displayed a knowledge of principles such as no other ship-designer of that time seems to have possessed, and in most of these features his intentions were realised. To him large dimensions caused no fear. 'The use of iron,' he remarks, 'removes all difficulty in the construction,' and experience of several years has proved that size in a ship is an element of speed, strength, and safety, and of greater relative economy, instead of a disadvantage, and that it is limited only by the extent of demand for freight, and by the circumstances of the

ports to be frequented." We have here almost all subsequent development predicted and summarised.

The presence of an inner skin and cellular bottom in almost all ocean-going ships of to-day—originally deduced, as has been stated, from wrought-iron bridge structural practice, and introduced in the *Great Britain* and *Great Eastern* on the score of the increased longitudinal structural strength it afforded—also justifies itself on the grounds of the convenience it confers upon ballasting both cargo and passenger-carrying vessels, and, especially in those of the latter class, the greatly enhanced safety it secures. Broadly and briefly described, the cellular system consists in the fitting, in a thoroughly water-tight manner, and sufficiently high to be accessible for inspection and painting, of a double or inner skin, extending across the vessel to the outer skin at the turn of the bilge. A series of longitudinal plates are worked fore and aft, set vertically between the outer and inner bottom plating, and connected to both by continuous angles. Between these longitudinals are transverse floor-plates, at every second frame, lightened with oval man-holes, and connected like the longitudinals by angles to the outer and inner bottom plating. As regards the increased safety it secures, many very notable instances might be given in support of the value of the cellular bottom in cases of passenger vessels having struck submerged rocks, torn very large portions of the outer shell, thus admitting the sea, and still, because of the inner bottom remaining intact, the vessel and her living freight being in no

danger. The *Great Eastern* herself furnished a notable and representative example of this on one of her early voyages. She ran on the rocks off Montauk Point and tore a hole in the outer skin 80 feet long by 10 feet broad, but proceeded to New York, her passengers being unaware of the damage done. A more recent instance is that of the *Paris*, which in May, 1899, went aground on the Manacles, and because of her inner bottom and splendid subdivision arrangements was ultimately got off after being on the rocks for over a month. On the other hand, many instances might be given of vessels foundering when it has been absolutely certain that the presence of an inner bottom would have saved the vessel and all on board; one memorable case being that of the *Drummond Castle*, which foundered off the Spanish coast in June, 1896, with the loss of 250 lives.

While thus so important an element of safety in passenger ships, and of requisite structural strength in those of exceptional dimensions, the double bottom in cargo-carrying vessels, and those of moderate dimensions, justifies its presence, as has been said, more on grounds of lending itself to rapid and convenient ballasting. It was in this connection at least that the system had primary and ready vogue in vessels built on the Tyne for coasting service, in which water became the substitute for rubble ballast—such vessels, for example, as were engaged in the coal trade between Newcastle and London, or in other trades where the full complement of cargo could only be obtained by shifting from port to port. Double bottoms for water ballast also form



DOUBLE-BOTTOM STEAMER ON THE STOCKS AT CLYDEBANK, PARTLY IN FRAME

an almost indispensable feature in modern sailing ships.

On the Clyde, as well as on the Tyne, builders were not slow to recognise the value of the double-bottom system as associated with water ballast in general cargo-carrying steamers. Messrs. Inglis, of Pointhouse, and Denny, of Dumbarton, during the period from 1878 to 1880, submitted proposals for double-bottomed steamers, and the latter firm, in 1878, built four sister vessels for the British India Steam Navigation Company on this principle. They afterwards raised the question with the Board of Trade as to the tonnage measurement of these vessels, and after protracted disputation they won from the Board the considerable concession of exemption from measurement for tonnage of the space occupied by the cellular bottom. The point gained had, of course, a very considerable influence in popularising the system with shipowners. Other Clyde firms, besides those named, took the matter up, and independently helped on the spread of the cellular mode of construction. Speaking in the early part of 1880, Mr. William John, of Lloyd's Registry, said: "At the time Mr. Martell read his paper on water-ballast steamers before the autumn meeting of this institution (Naval Architects) at Glasgow, in 1877, there had been only two or three small steamers built (since Scott Russell's early ones) on the longitudinal principle. Now, it is within the mark to say, there are one hundred steamers, built and building, whose bottoms are constructed on the longitudinal principle, or what

is better described as the cellular system, amounting probably to 200,000 tons, and it is not outside the bounds of probability that a very few years will see the majority of merchant steamers constructed in this manner." The intervening period has very fully justified this forecast, because, as already indicated, the cellular bottom is a feature in practically every ocean-going ship of to-day.

Another vital feature in modern ships which has neither cheapness nor convenience to recommend it, but is yet realised to be indispensable from the point of view of strength and safety, is the subdivision of the hull by watertight bulkheads. The primary object and ruling principle of all proper watertight subdivision is so to limit the space to which water can find access, that in a vessel with one, or even two, compartments open to the sea the accession of weight due to the filling of these compartments will not exceed the surplus buoyancy the vessel should possess necessary to keep it afloat. This, for long, was not fully regarded as it ought, owing chiefly to the objections of shipowners to minute subdivision as impairing a vessel's usefulness and capacity for stowage of miscellaneous cargo. These objections still apply, doubtless, to vessels in certain trades, but the exigencies of modern merchant carrying, the demands of the classification societies, the favour with which insurance companies regard vessels complying with such demands, and, above all, the unwritten but greatly more forceful demands of the travelling public, are influences which have made themselves felt; until now, indeed, the faith is general

that reasonably well-divided ships generally are, in the long run, no less efficient, and quite as economical, as scantily divided ones.

The influence exerted by the Admiralty in stipulating for increased subdivision of the hulls of all merchant vessels eligible for state employment in times of war was not long in making itself felt, especially as concerns the vessels of the great ocean fleets. Prior to the year 1880 only thirty or forty large steamers in the merchant navy were so constructed as regards subdivision that they would have survived for a few minutes the effect of collision with other vessels, or of grounding on rocks; but in a few years—greatly owing to the stipulations referred to, and the encouragement which shipowners had in complying with them—there were few, if any, of the many first-class mail steamers turned out which were not so constructed.

Many instances of marvellous survival, as well as of appalling catastrophe and loss, might be given to illustrate the value of minute and careful subdivision of the hulls of vessels by watertight bulkheads; but this has perhaps been sufficiently touched upon in what has just been said about double bottoms. The fact that bulkheads are so paramount a consideration in modern ships is all that need be emphasised. Unless, however, bulkheads are carried a few feet higher than the level of the water outside, they are valueless, and had better not be in the ship at all. They will contribute to the loss of the vessel by keeping the water at one end and carrying her "bows-under," whereas if they are not fitted, the same volume

of water will distribute itself throughout the bottom of the ship fore and aft, preserve the even trim of the vessel, and allow more pumps to cope with the inflow. Although her "freeboard" or height of side above water will be reduced, she will still be seaworthy; the boiler fires may be kept burning and the machinery going sufficiently long for her to reach a port of safety. Readers appreciating the above considerations will readily see why it is that sailing vessels are usually fitted with only one transverse bulkhead—that near the bow—and understand how it is that the outcry sometimes made by inexperienced people about the absence of other bulkheads in emigrant sailing vessels is for the most part unheeded by those on whom the responsibility falls. The bulkhead near the bow—the "collision" bulkhead, as it is termed—has done noble service in many cases of collision, and it is with reason that its position and structural character in all vessels are subject to special supervision and made a condition of classification in the Shipping Registries. The requirements of these bodies and of the Board of Trade constitute at once an anticipation and a reflex of the needs of merchant ship construction in watertight subdivision as in other matters.

Subdivision, of course, if minutely enough carried out, would make ships absolutely unsinkable; but such wholesale regard for the principle is, of course, hardly practicable, and is commercially quite unfeasible. For one thing, the question of convenience and necessity of getting about the ship from one compartment to another, especially in the machinery and coal storage sections, interposes itself. Doors of

communication are required, and these, fitted in the bulkheads, while a source of convenience, are also largely an element of risk. Ships have been built without the bulkheads being pierced for doors at all, except at a height safely above the water-line; but disadvantages far outweigh the benefits secured. It must be remembered that though provision against the dangers of collision and of stranding must be made, a ship of commerce is not built entirely with a view to the happening of these eventualities. With capable and careful navigators, provided with all the scientific aids to navigation now available, it is by no means inevitable that a ship should be in constant jeopardy. The records of Lloyd's and of the Official Registrar of Shipping continually show that a large proportion of better-class ships are broken up when past the work for which they were intended. In this connection we may mention as examples the *Great Eastern*, the *Alaska*, the *City of Rome*, the *Pavonia*, *Cephalonia*, and *Servia*, of the Cunard Line, and (perhaps more notable than any) the White Star liner *Britannic*, which was sold to be broken up after about thirty years' service, during which she travelled close on two million miles.

It will, of course, be readily enough understood that the provision of bulkhead doors, easily worked and efficiently watertight, has been a fruitful field for the inventor. The late Benjamin Martell, for long Principal Surveyor to Lloyd's Registry, in 1897 read a paper before the Institution of Naval Architects, in which he gave particulars of no fewer than twenty different patented doors and appliances for rapidly

and effectively opening and closing them. One of these consisted of a revolving double door—Kirkaldy's Patent—which involved the paradoxical property of always being closed and at the same time always being open. Briefly, this consists of an outer cylinder with two apertures—one at each opposite side, and an inner revolving cylinder with one aperture. The latter, in being moved round by the person passing through, has its aperture brought to correspond firstly with one, then with the other fixed aperture in the outer cylinder, and in this way a passage is effected. Scarcely any of the doors Mr. Martell described have received more than occasional and partial adoption; individual shipbuilders and shipowners having ideas of their own as to what is efficient and economical. Seeing that a door on the Kirkaldy revolving principle (always open, and at the same time always closed) most nearly approaches the ideal—ideal, of course, from the point of view of safety, rather than of practical convenience—of having no doors whatever in watertight bulkheads, the idea may yet have a future in both naval and passenger ships. On the other hand, it is not beyond the bounds of the possible that doors through watertight bulkheads may yet be obviated almost entirely by reason of the adoption and perfecting of electric lifts, of liquid fuel, of internal combustion engines, and generally of many other matters now being developed which affect the internal economy and working of ocean ships.

The rapid and simultaneous closing of bulkhead doors—a very vital point in connection with this

matter—has brought forth numerous inventions, in which hydraulics and electricity form the motive power. One method of actuating bulkhead doors, which has of late received extensive adoption in high-class mail and passenger steamers, is that known as the Stone-Lloyd system, and as representing the conditions to be met in fulfilling modern provisions for safety it may be noticed somewhat fully. This so far has been most completely adopted in the fast steamers of the Nord-Deutscher-Lloyd and Hamburg-American Lines. The Cunard Company have fitted it into their new steamers, *Caronia* and *Carmania;* while it is also installed in many of the newer cross-channel steamers. The motive power of this system is entirely hydraulic, though electric gongs are used for signalling the closing of the doors. Each door shuts at a regulated speed—sufficiently gradual to avoid danger by accident—by hydraulic pressure developed in and maintained continuously at 650 to 700 lbs. per square inch by special pumps and accumulators, and carried throughout the ship by copper pipes. The pressure operates hydraulic cylinders and appropriate gearing at each door, and the whole is actuated by a lever high up in the chart-house on the bridge. When danger threatens, the officer of the watch has simply to touch this lever in order to set the hydraulic engines to work, and thereby cause all doors in the ship to close themselves simultaneously in less than half a minute. He has but to touch a corresponding lever and the doors, by the same power, open themselves. In order that those seeking escape through the door-

ways may not have their chances destroyed, electricity, as mentioned above, is employed to give a warning signal. Movement of the shutting lever makes electric contact, and actuates a bell fitted in the neighbourhood of every door, which rings for a short time before the hydraulic power, coming into play, sends the door down. Should, however, any man be imprisoned in a compartment by the closing of the door, provision is made whereby it can be opened by a handle on each side of the bulkhead, which actuates steel wires connecting with the lever which controls the valve admitting hydraulic power to the actuating machinery. When so opened the door automatically closes itself again and leaves everything safe. Every contingency seems to be provided for. The vessel, for example, may strike a derelict or graze a submerged rock, giving no warning in advance, and thereby open her bottom to the inroads of the sea. In such a case there is an arrangement of buoyant float, with gearing, which the sea in entering puts automatically into operation and closes the door.

One other radical line of development in shipbuilding which appeals for mention while the subject of increased safety of ships is being treated—although its *raison d'être* lies more with increased propulsive power, as afterwards shown—is that of the fitting of twin or duplicate sets of engines and propellers. For river service and pioneer work in various parts of the world, twin-screw vessels were very early in evidence, and for coasting and cross-channel work, where two screws are necessary or advantageous, considering

the restricted depth of water available, and where manœuvring facility is a desideratum — in naval vessels especially—the great advantages of twin propulsion are now fully realised.

The comparative efficiency of single-screw and twin-screws for vessels of ordinary size was long debated by naval architects, but the conditions under which the evolution of the Atlantic *express* steamship proceeded made it imperative that twin-screws should be employed. In vessels having engines developing indicated horse-power ranging from 15,000 to 20,000, it was recognised as inadvisable, even though practicable, to transmit the whole of this stupendous power through one line of shafting. The risks run, through mishaps to the shafting or propellers of single-screw steamers, have received only too frequent illustration, and with the great decrease, or almost total extinction, of sail-spread in the larger steamships, now common, the consequence of such disablement have been rendered greatly more serious. With twin-screws, each driven by a separate and self-contained set of engines and shafting, ships can, in the event of a breakdown to one set of machinery, still pursue their voyage by means of the other set, although somewhat crippled in speed. Innumerable instances of this might be pointed to on routes of almost equal importance and even greater length than that of the Atlantic. In the event also of an accident to the rudder or steering apparatus, the twin-screw vessel can be manœuvred and steered by using the two sets of engines alternately. Finally, also, the duplication of the propelling machinery

enables the machinery compartment to be more minutely subdivided, thus enhancing safety in the event of collision and grounding.

The competition of the great Atlantic lines to have a ship larger and speedier than the latest addition to their several fleets is too well known, and is not so essential to our subject as to bear anything but the briefest recounting. Increased speed being the dominant aim in this competition, it is in this connection that our brief references here are made. The White Star Line with its fine steamships *Britannic* and *Germanic*, built in 1874–5 and embodying many distinct features, held for a considerable period first place in the matter of fast passages, 7 days 11 hours out and 7 days 17 hours home representing about the best performances. These in time were beaten by the newer ships, *Gallia* of the Cunard and *Arizona* of the Guion Line, which reduced the crossing by some hours. In 1881 the *Servia* was produced for the Cunard Line by J. and G. Thomson, Clydebank, her dimensions being 530 feet by 52 feet by 44 ft. 9 in., and in the same year, the *Alaska*, a slightly smaller, lighter, but much speedier vessel was produced for the Guion Line by John Elder and Company of Fairfield. This same year also saw the *City of Rome* produced for the Inman Line by the Barrow Shipbuilding Company. The *Aurania* of the Cunard Company followed in 1882 from the Clydebank yard, the *Oregon* in 1883 from Fairfield, and the *America* the same year from Clydebank, the rivalry culminating for a time in 1884–5 in the building by the Fairfield Company of the

Cunarders *Umbria* and *Etruria*, the latter of which had by the year 1888 brought down the outward voyage to 6 days 1 hour 55 minutes, which on a total distance run of 2,855 miles showed an average speed of 19½ knots, and on the homeward voyage to 6 days 4 hours 36 minutes, which on a total distance run of 2,890 miles gave also an average speed of 19½ knots. Increased dimensions, power, and speed, as has been indicated, characterised these vessels more than any notable features in construction; but in the material of which some of them were built—beginning with the *Servia* in 1881—a departure of great importance was made. This was the employment of mild steel in place of iron: a change whose introduction and gradual development will be dealt with later, and which in itself was greatly contributory to the enhanced safety of ships.

In 1889 four larger, more powerful, and in several respects more notable steamships than any preceding ones were ushered into the Atlantic service. These were the steel-built *City of New York* and *City of Paris*, produced at Clydebank for the Inman Line, and the *Majestic* and *Teutonic*, built at Belfast for the White Star Line. All of these were fitted with engines, shafting, and propellers in duplicate, and formed the inaugurators of the present twin-screw era in high-speed ocean mail service; the *Notting Hill* and other three similar vessels of the same line, built in 1881–4, which were really the first of the twin-screw ocean-going type, being only of moderate speed and chiefly for cargo-carrying purposes. The *City of Paris* in 1889 brought down the outward

passage to 5 days 19 hours 18 minutes, and covering a distance of 2,788 miles in that time, showed an average speed of slightly over 20 knots; and the homeward passage of a total distance of 2,784 miles yielded practically 19½ knots. In 1892 these vessels, inspired perhaps by the rivalry of their two White Star compeers, did even better, and maintained an average speed, both on the outward and homeward voyages, of from 20 to 20½ knots. The *Majestic* and *Teutonic* in 1891 attained an average speed on the outward voyage of 20·11 and 20·35 respectively, and on the homeward voyage in the same year the *Teutonic* attained an average speed of 19·79 knots. Two Continental companies had meanwhile been also enterprising and progressive, and in 1890–1 the North German Lloyd Line added to its fleet the fine native-built twin-screw vessels *Spree* and *Havel*, and the Hamburg-American Line with the Stettin-built *Fürst Bismarck*, the Mersey-built *Columbia*, and Clyde-built *Normannia*, took first place amongst Continental companies. In 1891 the Compagnie Générale Transatlantique, which had been running vessels between Havre and New York since 1862, added to its fleet *La Touraine*, one of the finest, though by no means the fastest, vessels ushered into transatlantic service, and the same company added in 1900 two even finer steamers—*La Savoie* and *La Lorraine*—which with a trial speed of 22 knots maintain a sea speed of about 20½ knots.

The year 1892 saw the beginning of another attempt on the part of America, with at least equal determination as in the previous "Collins" rivalry of

the Cunard service, to obtain a share of the Atlantic traffic and honours. The two fast Inman liners, which had always represented American capital, were transferred to the United States Register, and under the flag of the "International" company subsequently plied between Southampton and New York. The *St. Louis* and *St. Paul*, the first steamers built by the Americans for the Atlantic service since about 1870, and by far the largest ever built by them, were added to the International fleet in 1894, but the honours in the race still remained with vessels of the Old World.

The Cunard Company realising that the time had fully arrived when fresh forces should be brought into the arena, especially with the traffic likely to be created by the great Chicago Exhibition of 1893, requisitioned the able services of the Fairfield Company for the production of two twin-screw steamers, larger and more powerful than any yet afloat. These vessels, the *Campania* and *Lucania*, have been in service since the year mentioned. They are 620 feet over all, 600 feet between perpendiculars, 67 ft. 3 in. beam, and 43 feet depth from upper deck. Each has a tonnage of about 12,950 tons, and an indicated horse-power of about 28,000. Their dimensions exceed those of the *Paris* and *New York* (as the Inman liners had been renamed by the International Company) by 73 feet in the length and 1 ft. 9 in. in the breadth; and those of the *Teutonic* and *Majestic* by 34 feet in the length, and as much as 8 feet in the beam. The new Cunarders, in fact, were but 67 feet shorter and 17 feet narrower than the great mile-post of progress in this respect, the *Great Eastern*. The

maiden run of the *Campania* from Queenstown to New York was made in 6 days 8 hours 34 minutes, thus creating a record some two hours better than that established by the *Majestic*. Subsequently, in August, 1895, the *Campania* made the run between Queenstown and New York in 5 days 9 hours 6 minutes; the *Lucania*, in October of the previous year, having accomplished the voyage in 5 days 7 hours 23 minutes.

Into minute details of competing performances on the part of these and other British and Continental "fliers," such as the "distance run," the "time of year," the "best daily performances," and the "absolutely fastest passages" by minutes or even hours, we cannot here enter, nor is there need for this. The advent, in 1889, of the White Star Line's great steamship *Oceanic*, while a highly notable event from the shipbuilding point of view of increased dimensions and strength of structure (she being the first vessel to exceed the *Great Eastern* in length, 705 feet by 68 feet by 49½ feet) was not—as had been at first anticipated by the travelling and shipping public, but never intended to be by the owners—in any way a formidable competitor in the record-breaking contest. This was left for the competing German lines to take up, and the Hamburg-American Company with their splendid steamship *Deutschland*, built at Stettin, and put to service in 1900, and still more the Nord-Deutscher-Lloyd Line with their latest production, *Kaiser Wilhelm II.*, took up in 1902 the tale of record as to speed. Not to prolong the tale, it may simply be noted that these vessels, and particularly the latter,

with a length nearly the same as the *Oceanic's* (706.5 feet over all, 683 feet between perpendiculars, 72 feet beam, 25½ feet depth, gross tonnage 19,500 tons), at once secured, and the latter presently holds the "Blue Ribbon" of the Atlantic, with a series of unparalleled performances represented in the fact that her maintained average speed on service has, up till now, ranged from 23 to 23½ knots. The German ships, it should be noted, have to cover about 200 knots more than the British ships on the trans-atlantic voyage between New York and their nearest European port of call. To maintain the same length of passage between terminal ports involves roughly 7 per cent. increase in speed over the *Campania* and *Lucania*, and hence the necessity for the 23 to 23½ knots in the German vessels built to compete with and excel the Cunard ships. But the Cunard Company are now in the thick of retrieving lost ground in respect of speed on the Atlantic, and with substantial Government aid—for prospective value in return—they are having two great vessels constructed which are to be capable of maintaining a sea speed of 24½ knots. With the advance in speed this project involves, competing German ships must show a gain on the present ships of twelve hours, involving a sea speed of 25½ to 26 knots, with an enormous increase in dimensions, power, first cost, and working expenses. State aid, not hitherto lacking in Germany in any task regarded as important to Imperial interests, will at least have to be maintained, should the present position of German-built ships on the Atlantic service be improved upon; but of this something will be said

later when triple-screw and turbine-propelled vessels are considered.

The growth in the size of ships, restricted as this was by the comparatively slow progress evinced by iron manufacturers in providing longer and stronger structural items, within requisite limits as to weight, as well as by the uncertainty as to uniform quality, in time drew attention to the claims of "mild steel." The introduction of this now practically universal material has already been briefly alluded to as contributing both to the increased strength and the enhanced safety of ships, and the general facts may now be recounted, although necessarily steel will have to be treated of again when the subject of its use and behaviour in the shipyard comes to be dealt with. Although the introduction of steel, manufactured on the "Bessemer" or other process, as a material suited to the needs of the progressive shipbuilder dates as far back at least as 1860, its use had been but partial and occasional until about the year 1875, when mild steel, giving every promise of freedom from the risks incidental to early manufacture, was adopted by the British Admiralty in the construction of several naval ships. It was, however, in the dockyards of France that the steel now universally employed was first put into actual use in 1874. In the latter end of that year, Admiral Sir W. Houston Stewart, Controller of the British Navy, and Mr.—later Sir N.—Barnaby, Director of Naval Construction, availed themselves of an opportunity of studying the use of steel in the dockyards of L'Orient and Brest, where three first-class armour-plated vessels were then being built of

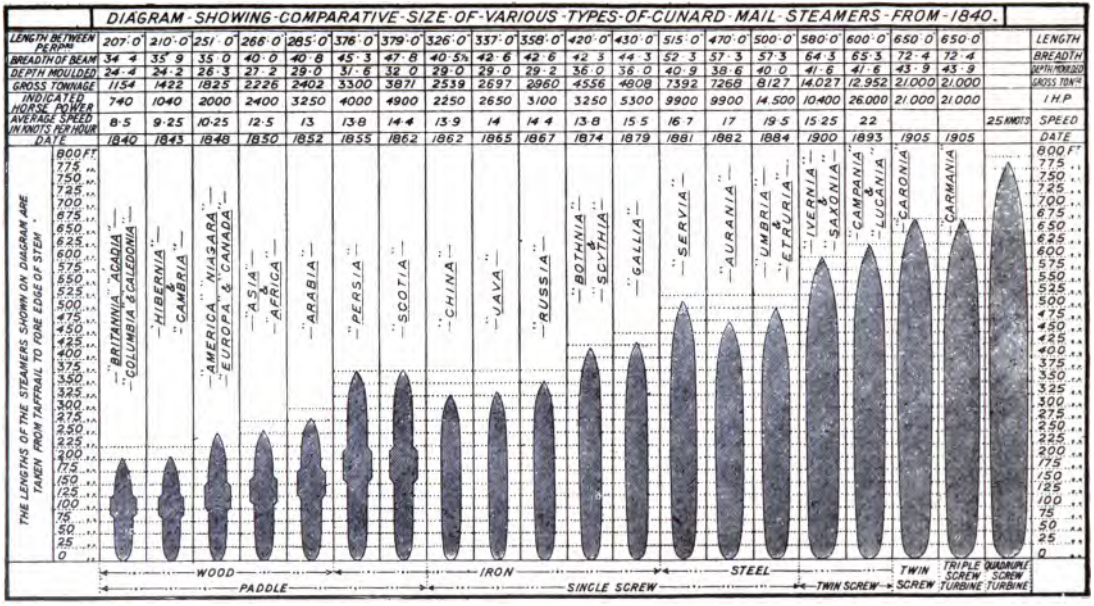


DIAGRAM · SHOWING · COMPARATIVE · SIZE · OF · VARIOUS · TYPES · OF · CUNARD · MAIL · STEAMERS · FROM · 1840.
LENGTH BETWEEN PERPDNS
BREADTH OF BEAM
DEPTH MOULDED
GROSS TONNAGE
INDICATED HORSE POWER
AVERAGE SPEED IN KNOTS PER HOUR
DATE
207·0 210·0 251·0 266·0 285·0 376·0 379·0 326·0 337·0 358·0 420·0 430·0 515·0 470·0 500·0 580·0 600·0 650·0 650·0
34·4 35·9 35·0 40·0 40·8 45·3 47·8 40·5¾ 42·6 42·6 42·3 44·3 52·3 57·3 57·3 64·3 65·3 72·4 72·4
24·4 24·2 26·3 27·2 29·0 31·6 32·0 29·0 29·0 29·2 36·0 36·0 40·9 38·6 40·0 41·6 41·6 43·9 43·9
1154 1422 1825 2226 2402 3300 3871 2539 2697 2960 4556 4808 7392 7268 8127 14.027 12.952 21.000 21.000
740 1040 2000 2400 3250 4000 4900 2250 2650 3100 3250 5300 9900 9900 14.500 10.400 26.000 21.000 21.000
8·5 9·25 10·25 12·5 13 13·8 14·4 13·9 14 14·4 13·8 15·5 16·7 17 19·5 15·25 22 25 KNOTS
1840 1843 1848 1850 1852 1855 1862 1862 1865 1867 1874 1879 1881 1882 1884 1900 1893 1905 1905
LENGTH
BREADTH
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THE LENGTHS OF THE STEAMERS SHOWN ON DIAGRAM ARE TAKEN FROM TAFFRAIL TO FORE EDGE OF STEM
800 FT 775 750 725 700 675 650 625 600 575 550 525 500 475 450 425 400 375 350 325 300 275 250 225 200 175 150 125 100 75 50 25 0
"BRITANNIA" "ACADIA" "COLUMBIA & CALEDONIA"
"HIBERNIA" "CAMBRIA"
"AMERICA" "NIAGARA" "EUROPA" & "CANADA"
"ASIA" & "AFRICA"
"ARABIA"
"PERSIA"
"SCOTIA"
"CHINA"
"JAVA"
"RUSSIA"
"BOTHNIA" "SCYTHIA"
"GALLIA"
"SERVIA"
"AURANIA"
"UMBRIA" & "ETRURIA"
"VERNIA" & "SAXONIA"
"CAMPANIA" "LUCANIA"
"CARONIA"
"CARMANIA"
WOOD
IRON
STEEL
PADDLE
SINGLE SCREW
TWIN SCREW
TWIN SCREW
TRIPLE SCREW TURBINE
QUADRUPLE SCREW TURBINE

DIAGRAM SHOWING GROWTH IN DIMENSIONS, ETC., CUNARD MAIL STEAMERS

steel throughout, supplied from the works at Creusot and Terrenoire. Mr. Barnaby, at the meetings of the Institution of Naval Architects in March following, gave an account of his observations during this visit, and pointed out clearly and precisely to the steel-makers of Great Britain all the indispensable conditions which would have to be met by steel for shipbuilding, so that it could be used with confidence in the construction of the largest vessels. Before the end of 1875 the company owning the Siemens Steel Works at Landore, South Wales, was enabled to produce material by the "Siemens-Martin" process, fulfilling all the conditions stipulated for by Mr. Barnaby. The Admiralty thereupon contracted with this company to supply plates and angles necessary for the construction of the cruisers *Iris* and *Mercury* then being laid down. Papers on the subject of the new material were read before the Institution of Naval Architects, and soon the general consensus of opinion was that the material—especially with the improvements likely to be made in its manufacture —would entirely replace iron in the construction of vessels. This, to be brief, was not very long in being realised in practice, in spite, of course, of the usual doubts and fears of the conservative. Plant for the manufacture of steel on this system began to be laid down in various parts of the country, one of the earliest, and all along up till now one of the most important, of such works being the Steel Company of Scotland, whose first manager, Mr. James Riley, brought his unique experience from Landore, and did and said much to influence the spread of steel shipbuilding.

The steel furnished by these different works, subjected as it was to systematic and severe tests, continually applied, was soon found to be possessed of the qualities of ductility, malleability, and homogeneity, which rendered its employment in shipbuilding not only permissible, but highly desirable. The experience of all who had practical dealings with the material in the shipyard was that it entirely satisfied —even more than iron—all the requirements of easy manipulation. The confidence with which it could be relied on, as to its certain and uniform qualities, placed it on a much higher level than the steel formerly manufactured; and its superiority over the best wrought-iron as regards strength and ductility rendered it a highly preferable material. Progressive shipbuilders on the Clyde—notably William Denny and Brothers, Dumbarton—at an early stage took up mild steel, demonstrated its advantages, and induced shipowning friends to adopt it in their new vessels. The earliest ocean-going steel steamer was the *Rotomahana*, built in 1879 by the firm named for the Union Steamship Company of New Zealand, and this was followed in 1880 by the *Buenos Ayrean* for the Allan Line, which was the pioneer steel Atlantic liner. The Allan Line had not had possession of this vessel more than nine months when the company gave the order to Robert Napier and Sons, Govan, for another and much larger steel vessel, the *Parisian*. Besides the companies already named, the Pacific Steam Navigation Company, Donald Currie and Company, and several other smaller companies ordered vessels of steel almost simultaneously, while

yet the new material was on its trial. Amongst the orders subsequently given for steel vessels of importance, that for the Cunard Company *Servia* has already been mentioned, and others were the *Catalonia* for the same company; the *Clyde*, *Thames*, and *Shannon* for the Peninsular and Oriental Company; the *India* for the British India Company; and the *Arabic* and *Coptic* for the Oceanic Steam Navigation Company.

While doubt still existed, however, as to the economical advantage of adopting steel, there was hesitancy evinced on the part of shipowners generally and, of course, of ship insurance societies, as well as other bodies concerned. Lloyd's Registry was led—but not without great and perhaps quite politic reluctance—to make considerable concessions in the matter of the thickness of the material necessary for ships of given proportions. The reductions eventually allowed in vessels built to this Registry's requirements were 20 per cent. in scantling and 18 per cent. in weight. As it was impossible to adjust the scantlings of material to take the full advantage of these reductions—an allowance having to be made for extra weight due to the continued use of iron for certain purposes in vessels of steel—the average weight-saving effected in practice was about 13 to 14 per cent. This represented in the finished vessel a clear increase of at least 13 per cent. in dead-weight carrying capability.

The first cost of a steel ship was for long considerably over that of an iron one, even considering the reduction in weight of material which the use of steel permitted of. In 1877 mild steel was about

twice as costly as the iron in common use. The sources of supply, however, were then comparatively few, and the thorough and severe testing to which the new material had to be subjected necessarily increased the cost relatively to iron, which had never been subjected to the same rigorous ordeal. Messrs. Denny Brothers forced upon the registry societies the economic importance of testing and approving—or of rejecting—material at the works of the makers before it was despatched to the shipyards. In 1880, owing to the increased sources of supply and the progress in manufacture, the cost of steel had been reduced, relatively to iron, by about 50 per cent. Notwithstanding this, in 1882 a spar-decked steamer of 4,000 tons gross built in steel cost, in excess of a similar one built in iron, the sum of about £3,600. This disparity in cost, however, has been gradually reduced by the combined efforts of the steel-makers, the shipbuilders, and the other chief interests concerned. The reduction permitted in steel scantling to-day by Lloyd's rules is equivalent in the finished vessel to 12 per cent. of what the weight would have been had iron been employed, but, as a matter of fact, iron ships are now a rarity, and steel is cheaper and much more conveniently obtained than iron.

Doubts were at first freely expressed by not a few regarding the durability of steel ships compared with those of iron, such misgivings, of course, being aggravated by the thinness of the steel plating, and possibly by cases here and there of rapid and at that time unaccountable deterioration. With larger experience of the material and how to treat it, both in

the working and in its protection afterwards, and also, no doubt, with the constant improvements in its manufacture, this early disadvantage and fear, it may briefly be said, have not been justified. Undoubtedly, however, all experience proves that steel vessels require more constant and careful treatment with protective paints than was generally bestowed upon iron ones. Insurance societies, having regard to the enhanced safety of steel ships, as was soon notably demonstrated in cases of mishap at sea, were not long in taking steel ships into their favour and reducing premiums. Through these and other influences, which need not further be dwelt upon, steel has become the all but universal shipbuilding material of to-day.

Different processes of manufacturing steel have, of course, been introduced, and the cost of suitable material, complying with the conditions as to strength and quality laid down by the register societies, is, as has been said, now under that of ordinary iron. Iron ships indeed are now scarcely ever built, and the once prevailing material is only introduced in certain parts of ships' structures where there is extra liability to corrosion and wear, and where rigidity and dead-weight more than strength are required. Steel of varying tensile strength or of more or less degree of hardness, is also now being used in given parts of a vessel's hull according to the stress which these parts may be subject to, in the course of her life and work at sea. Steel, alloyed with a percentage of "nickel," which greatly enhances its tensile strength, is now being employed, and has, no doubt, a great

future. With the more plentiful supply and cheapened cost of "nickel," ships of nickel-steel will be greatly increased in strength with the same weight. Further growth in dimensions will thus be rendered possible and safe, or with the same dimensions higher speeds will be secured through a reduction in weight of hull. Nickel-steel is now also used for marine shafting and other forgings and castings, for boiler tubes, etc.

While tonnage or mere bulk is not necessarily a measure of the importance of shipbuilding productions, some figures are worthy of being given here showing the companies who have enlisted the services of shipbuilding in the production of leviathan ships within recent years, many of the single productions, of course, being notable specimens of the finest and most elaborately fitted liners of high speed. Taking only into consideration vessels of 12,000 tons and upwards, and beginning with the *Campania* and *Lucania* produced by the Fairfield Company in 1892–3, there were built or building, as at the end of 1903, forty-seven vessels aggregating close on 674,000 gross tons, the average tonnage of which was 14,330 tons. This summation includes notable vessels built both in Britain and abroad, *e.g.* the Belfast-built *Oceanic* of 17,274 tons, *Celtic* of 20,904 tons, *Cedric* of 21,035 tons, and the *Baltic* of 23,763 tons; the German-built *Deutschland* of 16,502 tons, the *Kaiser Wilhelm II.* of 19,360 tons, and the American-built *Manchuria* and the *Mongolia*, each of 13,300 tons, and the *Minnesota* of 21,000 tons. Of all the firms engaging in such notable work, none

CUNARD LINER "CAMPANIA" ON THE STOCKS AT FAIRFIELD, GLASGOW

have approached in respect at least of average tonnage the Belfast firm of Harland and Wolff. Up to the close of 1903 they turned out twenty-four vessels of an aggregate tonnage of 351,422 gross tons, the individual average of which is no less than 14,643 tons. This firm has therefore exceeded the work of all other builders, British and foreign, in the number of such leviathan vessels by one, and the average tonnage by 630 tons.

The construction of these very large steamers is still proceeding apace. The White Star Line are having a duplicate of the *Baltic* built by Harland and Wolff, and there is also on the stocks of the great Belfast yard at present a leviathan "intermediate" steamer for the Hamburg-American Line of over 22,000 tons. The Vulcan Company, of Stettin, Germany, who have constructed all the successful high-speed Atlantic mail and passenger steamers for German lines, are now also engaged on leviathans of the intermediate order, one being for the Hamburg-American Company, and almost exactly a duplicate of the vessel under way at Belfast. This vessel is 676 feet long between perpendiculars, 77 feet beam, 54 feet depth moulded. When loaded to a draft of 33 feet, she will have a displacement of 35,000 tons. Her engines will develop 17,000 indicated horse-power, and give the vessel a speed of 17 knots. The Cunard Line have had built by John Brown and Company, of Clydebank, the *Caronia*, of 21,000 tons gross and intermediate speed; and there is at present undergoing completion the *Carmania*, a sister ship in all but the propulsive power, which is

on the turbine instead of the reciprocating system. On her official trials on the Clyde the *Caronia*, for which a speed on service of 18 knots was stipulated, attained a mean of over 19½ knots, the indicated power being about 21,800. The *Carmania*, with turbines, is expected to realise at least 20 knots. As size more than speed is here being noticed, reference to other notable vessels—including the new Allan Atlantic turbine liners *Victorian* and *Virginian*—will be made further on.

Having brought the subject of the growth in ships' dimensions—involving, of course, a consideration of concurrent and necessary improvements in structural features—up to the present day, the important—the almost vitally important—question of the mode of propulsion for such huge steamships naturally demands some attention. The introduction of the compound in place of the single-acting engine marked one of the most important advances in marine engineering. Watt, of course, had recognised the expansive properties of steam, and enunciated the true principles governing its use, but with the low pressures then used, the advantages of using the steam in two cylinders successively (the second cylinder being enlarged proportionately to suit the greater volume due to expansion) could not be fully realised. In 1854–6, with steam at an initial pressure of about 60 lbs., John Elder, one of the ablest engineers of his day, and founder, with Charles Randolph, of what is now the great Fairfield establishment, fitted four-cylinder engines, with jet condenser, into the *Brandon*, and in 1855–6 the paddle

steamers *Valparaiso* and *Inca* with four-cylinder diagonal engines. In 1858 he fitted into the *Royal Bride* a four-cylinder inverted direct-acting common condensing engine, but with this vital addition—it had as an accessory what has since that time remained a vital part of marine engines, viz. a surface condenser, although surface condensation had been introduced over twenty-eight years previously (1837) by Samuel Hall, of Basford; while it is said that Watt early suggested or used a surface condenser.

Broadly speaking, the effect of these two features, viz. double expansion and surface condensation, was the ability to utilise in the engines higher pressures of steam, and to dispense with water from the sea, which proved so deleterious to the boilers. By these changes, almost at once, a reduction in the consumption of fuel was effected of nearly 60 per cent.; in other words, the consumption fell from 5 to 7 lbs. per horse-power per hour to 3½ lbs. For more than a decade after the introduction of the compound engine the steam pressures generally in vogue remained stationary, but gradually, with experience as to the economy effected, and with concurrent improvements in manufacture of both engines and boilers, pressures rose—a marked advance taking place, of course, when circular boilers were adopted, and especially so when mild steel and the more capable tools employed for its treatment were established factors in the work of progress. Advance in pressure has also been marked since having been associated with triple and quadruple expansion engines. John Elder, it is worthy of note, in 1862,

included in one of his patents both triple and quadruple expansion engines, but it was only in 1882–4 that the practical introduction of these types of engines took place. The engineers sharing in the credit of this further advance were Mr. Alexander Taylor, of Newcastle, the late Dr. A. C. Kirk, then of Robert Napier and Sons, Govan, and Mr. Walter Brock, of Denny and Company, Dumbarton.

Under the multi-expansion system steam pressures attained to 150 and 160 lbs., and gradually advanced further, until now, in the mercantile marine, with the ordinary cylindrical boiler (with mild-steel shell, $1\frac{3}{4}$ and $1\frac{7}{8}$ inches thick, corrugated furnaces, artificial draught, superheaters, and other features for efficiency and economy), pressures of 210 to 220 lbs. are common, while a little less than 270 lbs. has been reached in a few cases. For warships, and with boilers of the water-tube type (with whose introduction and development the naval authorities of France, Britain, and America are mainly to be credited), pressures of 250 to 300 lbs. have been used since about 1894. In the cases of recent vessels, in which 20 per cent. of the total power is provided by cylindrical boilers, and the remainder by water-tube boilers, the pressure adopted is 210 lbs. Water-tube boilers, it may be added, have so far received but limited adoption in vessels of the mercantile marine, but in naval vessels—where their advantages are more pronounced even in face of the uncertainty as to their staying power—their employment has been rapidly extended. The result of a long period of inquiry by the Boiler Committee, who gave their final report

to the Admiralty in June, 1904, was to thoroughly establish the reputation of a number of the types tried. Out of four types selected for trial—viz. Babcock and Wilcox, Niclausse, Durr, and Yarrow —two, the first and last named, were found "satisfactory, and suitable for use in battleships and cruisers without cylindrical boilers."

As a result of the higher steam pressure, and all the other mechanical improvements which we have only been able to hint at, the economy of fuel in recent years has been remarkable. When pressures were only 5 lbs. and 6 lbs. it required 10 lbs. of coal to produce each single indicated horse-power exerted during an hour, whereas with a pressure of 200 lbs. the same amount of power may be obtained for as small a quantity as 1¼ lbs. of coal. When steaming at sea a vessel built twenty years ago, having engines of 1,000 horse-power, consumed some 2,000 lbs. of coal per hour; one of corresponding power, built twelve years ago—or early in the nineties—required only 1,750 lbs., while at the present day a 1,000 horse-power ship can easily maintain the same speed per hour on a consumption of 1,400 lbs. of coal. Consumption is thus 30 per cent. less than it was twenty years ago, and 20 per cent. less than twelve years ago, although credit for the advance must, to some extent, be accorded to the naval architect and steel-maker as well as to the marine engineer.

The introduction of twin-engines and propellers has already been sufficiently referred to when writing of the increased safety and speed of modern ocean liners. A further step in advance, involving the adop-

tion of triple-engines and propellers, must become general seeing enhanced size and speed continue to be the aim of the companies engaged in ocean mail and passenger trades. Coincidently, however, with the great acceleration in the speed of express steamships, there has grown in favour, even in the Atlantic service and in vessels for long voyages, the "intermediate" type of ocean ships, of larger dimensions and tonnage, but of moderate power and speed, and having sea-going qualities and features of safety and comfort not a whit less remarkable than in the latest type of express steamers. Large cargo-carrying power and more leisurely and comfortable pace on the ocean are features which distinguish these vessels. It will be understood, therefore, that in their case the need for triple in place of twin screws is not so imperatively forced on the attention of naval architects. In express steamers it is distinctly otherwise, and with the last possible increment of power and speed of such importance, the efficient use of three or more screws, actuated by the *rotary* in place of the reciprocating engine, is a problem pressing for, and now receiving, solution, even in ocean services. This highly important and, at present, keenly scrutinised line of development in ship construction and propulsion will afterwards be treated of. Meantime, in the following chapter, we deal at length with the actual daily work—scientific and practical—carried on in a representative modern shipyard, and as exemplified in the building of a high-class mail and passenger steamship.

CHAPTER III

SHIPBUILDING IN UP-TO-DATE SHIPYARDS

SHIPBUILDING as an art has long become subordinate to the science involved in the industry, while handicraft skill—not to speak of "rule of thumb" methods—has been largely superseded by mechanical operations and processes of almost mathematical exactitude. The primary, if not the chief, interest in the modern shipyard may therefore be said to centre in the designing or "drawing office," where in the first instance the technical qualities and conditions of design of each vessel are determined. These are according as the vessel (merchant ships mainly are here referred to) may have to be for swift mail and passenger service, for moderately speedy and large cargo-carrying service, or possibly for a combination of both functions, as exemplified in the modern "intermediate" class of ocean steamships. Of course, each of these divisions embraces a large number of possible craft deviating from the general type in respect of form, structure, and mode of propulsion, according to the place and character of service intended. High-speed, river, or channel service; light-draught, pioneering work in undeveloped parts

of the world; and vessels large and small, in which sails only, or possibly oil, gas, or electric in place of steam engines, are to be the motive power—all these are possible demands with which the naval architect and shipbuilder must deal on occasion.

With the general elements of design tentatively determined—and, of course, in this the owners or their technical advisers guide the shipbuilders a good deal—the lines on which the vessel must be built are drawn out on a small scale. Afterwards the model in wood is prepared, although in some cases, especially in America, builders prefer to make a model serve right off as the basis of design. The model lends itself better to the process of "pleasing the eye" by cutting and carving to the desired form, and the finished product is easily transferred to paper. Following the general design, as in this way determined upon, comes the detail or "working" drawings. In connection with vessels of very exceptional character —in which possibly questions of unusual form and of stability, speed, draught, etc., out of the normal are involved—the preliminary work and responsibility in designing are, of course, much enhanced. The part played by the designing staff in shipyards (or by independent outside naval architects) is in such cases, of course, a most responsible one. There are now a number of establishments—governmental, as well as private—where such problems are investigated and elucidated by experiments with models. In a way, this sort of experimental aid has been resorted to by well-known physicists from at least the beginning of steam navigation. Colonel Beaufoy, who

INTERIOR OF EXPERIMENTAL TANK IN THE SHIPYARD OF WM. DENNY AND BROS., DUMBARTON

made elaborate experiments with floating bodies in 1790–1800 on behalf of the society at that time established "for the improvement of naval architecture," David Napier on the Clyde, Robert Fulton in America, Scott Russell while engaged on the Clyde as the naval architect to the Royal Mail Company, and Professor Rankine of Glasgow University, as well as many other academic investigators in other countries, are all worthy of mention in connection with inquiries into the phenomena of flotation and resistance of bodies, ship-shape and otherwise. Following the "Cod's head and mackerel tail" principle of ship's form in vogue one hundred years ago—that is, vessels in which the bow-lines were very full and round, and the stern-lines fine and hollow—there came Scott Russell's "wave-line" theory, according to which the lines both fore and aft were made to take the form of the waves which are produced by the displacement and resettlement of the water, which he called "the wave of translation and the wave of replacement." In other words, the curves thus evolved are trochoidal in character, giving fine lines forward and fine lines aft. In order to get the same displacement with such lines the length had to be greatly increased, and the form varied, much with the necessities of each case. The present practice does not follow out the wave-line theory. Generally speaking, the lines forward are practically straight, except in full vessels when they are round, and in very high-speed vessels when they are slightly hollow. Experience has also shown that for low speeds the lines can be very much fuller without affecting speed than was for

a time supposed to be possible. This, it may briefly be said, is due to the fact that at low speeds "skin" or surface friction represents about 80 degrees of the total resistance, and therefore wave-making is a very small part of it. Very much larger cargoes can, in consequence, be carried at the same speed on the same dimensions, with such fuller lines.

These are only a few examples of the many modifications and improvements which investigation and experiment on the part of scientific men—some of them outside the profession of naval architecture altogether—have brought about. But it is to the late Dr. William Froude, of Torquay (brother of Froude the historian), that shipbuilders and designers are indebted for much of their most valuable experimental information regarding the law of speed and resistance. No one, indeed, has done more for the science involved in ship design than Dr. Froude, and virtually all the present-day methods of investigation in the science of ship propulsion are based on his researches and conclusions. The result is that designers are able now to predict beforehand, and with much greater accuracy than formerly, what the speed of any proposed vessel will be, or what power is requisite for any assigned speed.

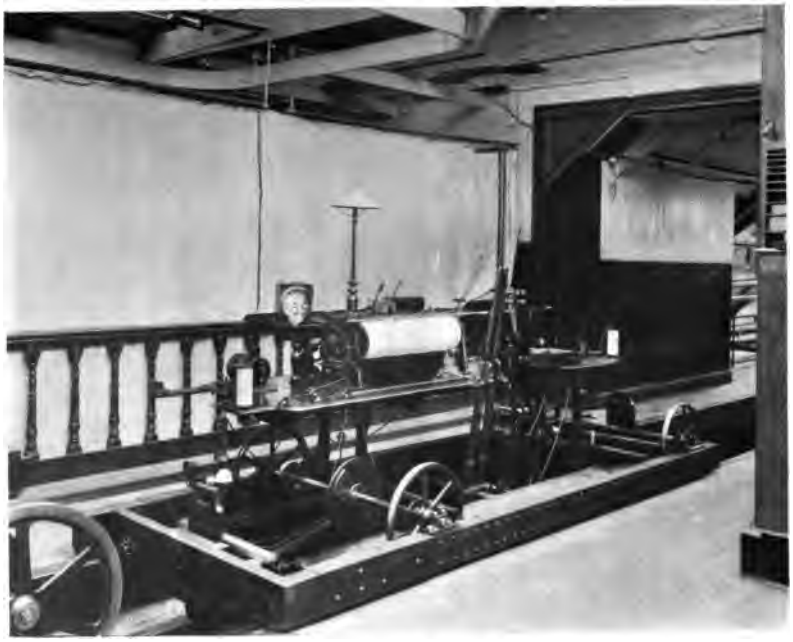
The essential feature of Dr. Froude's methods—apart from the laws which his genius deduced—is the observation of and comparison made between small-scale models of vessels towed through a large tank of water. He established a private tank at Torquay, in Devonshire, in 1870, and the systematised and reliable processes now in use in this country (where, in

the later governmental tank at Haslar, the work of experimental investigation in respect of all types of naval ships is carried on and developed by Dr. Froude's son, Mr. R. E. Froude) and in America, Holland, Russia, and Italy, are the direct outcome of his independent initiation of the system. Experimental tanks based on the original one at Torquay are now a feature, not only in the naval designing forces of the countries named, but in a number of colleges abroad, and in private yards, notably William Denny and Brothers, Dumbarton, and more recently John Brown and Company, Limited, Clydebank. In these latter cases, experiments with model propellers in conjunction with models of the vessels themselves form an elaboration of the original experiments of Dr. Froude. The Denny tank was established as far back as 1882, mainly through the scientific enthusiasm and far-sightedness of the late William Denny, who was a sincere admirer of Dr. Froude, and a staunch believer in the practical value of the deductions to be drawn from that scientist's investigations and methods. Two of the illustrations in this book (facing pages 82 and 86)—reproduced from photographs kindly supplied by the renowned Dumbarton firm—show the interior of their tank and the speed-recording truck, and other scientific apparatus connected with model experiments.

Without a tank, as long as a beaten track is followed, no doubt much can be determined by collating known data, but once a new relation is introduced, the use of an experimental tank becomes of great importance. Much of the success attending fast and

special naval vessels has been due to the Torquay tank and its successor at Haslar. Torpedo-boats and torpedo-boat destroyers, although not first suggested by the tank, are largely a result, both as regards dimensions and fineness of lines, of tank experiments. Increased beam in relation to length in modern ships, both for the naval and mercantile marine, is largely a development justified by tank experimental data. In the American tank at Washington special provision has been made for the needs of private individuals. It is but natural that the private firms possessing tanks do not consider it in every way expedient to draw public attention to the advantages they are deriving, but in this connection reference may be made to the declaration of Mr. Archibald Denny, made at the International Engineering Congress in 1893. He then said: "Had it not been for the tank, we should never have constructed the *Princess Henriette* and *Princess Josephine* (two high-speed steamers for the Belgian Government, running between Dover and Ostend); at least we would not have had the same assurance in taking the contract under such stringent conditions as we did." In 1901 the same gentleman remarked at one of the meetings of the Institution of Naval Architects, "Had we two tanks, we could use them both!"

It would almost appear that accumulated experience and modern science together are supposed to be all-powerful, and naval architects are often asked to fulfil so many onerous and sometimes conflicting conditions in one vessel, that the great preliminary difficulty is to persuade the shipowner that the naval



VIEW OF MODEL TRUCK IN THE EXPERIMENTAL TANK OF WM. DENNY AND BROS., DUMBARTON

architect's and shipbuilder's art has its limitations. The diminution of net register tonnage, on which dues are paid, relatively to the carrying capacity of vessels, is a problem often presented to the ship designer by keen shipowners. Enormous cargo-carrying powers on an almost impossibly light draught of water is another feat demanded. Builders of the author's acquaintance have declared that it would not surprise them to be asked to "design a boat to sail over a grass park after a dew had fallen"!

There are, of course, a hundred and one ordinary and reasonable conditions which the designer has in almost every case to ponder over and fulfil as far as in him lies. These may be inferred from remarks made elsewhere, but it is convenient here to summarise a few. He has often to produce a vessel of a certain length, which must not be exceeded, and guarantee that it will attain a given speed with a given dead-weight on board, and not exceed a specified draught of water; that it will be at certain trims forward and aft, with certain weights in certain situations on board; that it will have a certain amount of space for cargo; that it will, if a passenger ship, be of such proportions and form that she will prove both a speedy and a steady ship at sea. Besides all these and many more conditions involved in the general design of ordinary merchant vessels, there are a hundred and one requirements to be met in the detailed arrangement and internal economy of modern ships, not only as vehicles and warehouses for goods, but as living habitations, not to say homes of luxury. High-

class passenger ships, for ocean service especially, and according to the exigencies of service and climate, must have all the appliances of a first-class modern hotel: light and ventilation, both natural and artificial; steam and coal cooking appliances; hot and cold water supply, both fresh and salt; refrigerating machinery, heating and cooling apparatus, etc. But before and above all these things, at least in passenger ships, are the provisions which must be made for the safety of the ship and her living freight under all conditions of service. "Fire" and "foundering" are terms which convey a lot of meaning in this connection. The provisions made against these dire contingencies are matters which vitally affect the structure as well as the equipment of vessels, and of course receive attention elsewhere. From all this it will be seen that the virtual creation of a ship, even of the most ordinary kind, begins in the drawing-office, and long before the visible or practical construction is initiated in the yard.

From the drawing-office, measurements or off-sets, taken from "the draught plan," or plan of the vessel's lines, are sent out to the different departments, and later the working detail drawings. The vessel's lines, as exhibited by the draught plan, consist of three sets of curves and straight lines, representing the contour of the vessel's hull on three distinct planes. The sheer plan shows, in longitudinal elevation, the water-lines at uniform heights, also the frame stations throughout the vessel's length. The half-breadth plan shows the deck margin-line and the water-lines from stem to stern. The body plan shows the lines

of traverse frames, or cross-sections, at given uniform stations, and of course presents the same appearance as the frames of the actual ship do to anyone looking at them, end-on, after their erection in place. There are other lines appearing on the draught plan, not so essential for exhibiting the hull-form as the others, but of the first importance in securing general fairness and symmetry. But it is not possible here to go more into detail. The measurements as taken from these several plans represent the general form of the projected vessel, and these are "off-set" and chalked down full-size on the floor of the "mould loft." On this surface, which is virtually an immense black-board, the lines are "faired" and sweetened, the process eliminating all irregularities and unfairness which may be due to the want of skill of the original draughtsman or to the process, even in skilled hands, of measuring from the small-scale plan. From the mould-loft lines, as thus perfected, wood moulds, or skeleton outlines, are prepared for the guidance of the workmen in the shipyard. The most important item thus prepared is the "scrive-board," a smaller wood floor usually situated near, or taken to the vicinity of, the frame furnaces and "bending-blocks," of which more will be learned immediately. On the surface of this scrive-board the shape of the transverse frames and floors, the line of fore-and-aft keelsons, etc., are outlined by pliant wood battens, and "scrived" or incised on the smooth surface by a sharp hand-tool.

Meanwhile the keel, frame-bars, plates, and other steel material for the vessel have been ordered from the makers or merchants, and gradually arrive in the

yard in the sequence required, and approximately of the precise dimensions and shape suited to their several places in the structure; thus diminishing the work of trimming and preparation to a minimum, and saving "scrap" or surplus material.

As most generally typical of the science and art of present-day shipbuilding let us assume that a modern mercantile leviathan ship is under notice. The keel of the ship—usually a massive flat bar, in conjunction with a second thinner plate keel, and deep vertical centre longitudinal plate and connecting angles—has been laid on the "keel-blocks," which are erected at suitable distances apart along the whole length of the building-slip. These are massive slabs of timber piled one upon another, usually to a height of four to five feet, with their upper surfaces conforming to the line of declivity necessary for launching the completed ship, of which more will be said later. With this fundamental member of the structure "well and truly laid" the frames are then brought from the bending-blocks—heavy iron slabs laid close together to form a level metal floor, solid and unwarpable—situated in front of the furnaces. Here the shape of each frame, as outlined on and transferred from the scrive-board, is drawn with chalk. All over the floor are round holes, closely spaced, and at equal distances apart. Along the line representing the shape of the frame stout pins are placed in as many of these holes, which impinge on the line, as may be necessary. The glowing bars of steel are drawn on to the floor from the adjacent heating furnaces, and bent round the curve of projecting pins in little more time

FRAME BENDING BLOCKS

PLATE BENDING ROLLS

than it takes to describe the process. In this, more perhaps than in any other of the important members of a ship's structure, the immense difference between the art or handicraft involved in wood shipbuilding and the mechanical simplicity of shipbuilding in iron is illustrated. There are here none of the elaborate process of selection of suitable timber, and of hewing and fashioning of parts requisite to form a single frame, seen in the former style of construction. In most of the larger shipyards, too, an apparatus called the bevelling machine is interposed between the mouth of the furnace and the bending-floor, the function of which is to impart to the fore-and-aft flange of the frame-bars the proper bevel adapted to the varying form of the ship, especially at the forward and the after ends. This bevel is imparted to the hot bars mechanically, and almost automatically, under the supervision of an attendant who manipulates the bevel gauge attached to the machine. In less up-to-date yards and in smaller vessels the fore-and-aft bevelling is done by "hand-and-hammer" of the frame-benders, but here, as in other directions, smart and accurate mechanical processes have almost supplanted slow and uncertain handicraft skill.

For very many years, while vessels continued to be of moderate dimensions, and especially prior to the general adoption of water-ballast bottoms in ships, each frame was formed of an ordinary angle-bar, in combination with a second bar, or "reverse frame," and a solid floor-plate stretching across the bottom of the vessel, the three items being riveted together. As thus combined, each frame on each

side of the vessel was in one piece from the keel to gunwale or upper-deck. Their erection on the keel was a comparatively simple matter. Each half was set on end at right angles from the keel and kept in position by heel pieces and by shores and rib-bands along the bilge and gunwale, binding the frames in succession. In vessels built on the cellular double-bottom principle the order of procedure is somewhat different. The frames are in three and sometimes four portions to the whole girth. One portion (when three portions are employed) corresponds to the bottom of the vessel, and extends across and through the centre longitudinal, terminating against the wing-plate on each bilge. When four portions are used one begins on each side of the centre longitudinal, to which it is securely attached, and ends against the wing-plate at each bilge. The remaining two portions form both sides of the vessel from bilge to gunwale, and are superimposed upon the wing-plate and firmly bracketed thereto.

The use of solid or single-section material, viz. bar of U-channel, Z-bar, and bulb-angle in place of riveted combinations, for the side frames and deck beams is now almost universal for the larger size of vessels. Mild steel has enabled manufacturers to provide for shipbuilders' requirements in this connection to a truly remarkable degree. The most obvious of the several advantages attaching to the use of such solid-section material is that it enables the shipbuilder to dispense with the reverse frame, the work of bending the latter, and of afterwards riveting it in combination with the angle-frame

CUNARD LINER "CARONIA" ON STOCKS, CLYDEBANK, SHOWING CELLULAR BOTTOM AND SIDE-FRAMING

proper. Besides this advantage there is the constant benefit to the ship—and to the owner—of a saving in weight, with the same, and even superior structural strength, the weight thus saved being, of course, available for cargo-carrying.

When the centre longitudinal and keel are laid and fitted, the bottom section of the framework is next fixed in place for the greater part of the vessel's length, the whole system of longitudinal and deep floor-plates is erected, and the strakes of plating forming the inner bottom laid and temporarily fixed. All this is done from end to end, as may be seen in our illustration facing page 52, before the side portions of the framework are set up, and each side frame "plumbed and horned"; that is, set accurately upright with regard to the keel level, and with the two side frames in the same vertical plane across the keel. With this accomplished the framing is complete; but the entire framework of the vessel is never seen as thus described because the clothing or plating of the framework begins on certain, and usually midship, portions of the ship, before the framing at the ends has been completed, and the stem and massive stern-frame are erected in place.

Work in various directions in connection with this imaginary modern leviathan has been under way in different departments, and now proceeds briskly. The deck planks have been cut in the sawmill and "stacked" to dry and "season" thoroughly; the cabin and other woodwork is being proceeded with in the joiners' and cabinet-makers' shops, etc.; the sails and boats are in hand, and the masts and spars

of wood and steel are being proceeded with in the sheds or spaces set apart for such work. Blacksmiths, brassworkers, plumbers, and other tradesmen are busy fashioning the fittings. The foundries and engine shops are preparing the great mass of complicated machinery, with its numberless accessories, for driving the vessel. In the boiler shops as well as at the building-berth, the smart and incessant rataplan of the riveters' and sheet-metal workers' hammers makes a busy din; although within recent years the forceful and quiet operations of hydraulic tools have worked considerable change in both places in this respect. All over the yard, in short, and in unsuspected corners, work is going forward that an inexperienced person would find it difficult to realise was converging to one point of general aggregation and rounded result.

To return to the building-slip. The ship carpenters hoist and fit the deck beams, which thus form, with the before-mentioned rib-bands, a tie to keep the frame section in true shape. The massive stern-frame, of forged iron or cast steel, on which the rudder as well as the propeller in single-screw steamers (and the propeller brackets in the case of twin-screw vessels) depend, is set in position, and the stem of forged iron or steel is also upreared. The athwartship bulkheads, which ultimately subdivide the hull into those watertight compartments, which, as we have seen, form so vital a feature in connection with the safety of modern ocean ships, are also erected in place, and the deck stringers fitted along the margin of the deck beams which connect them to the frames. But before the

bulkhead plates and the inner-bottom and stringer plates are brought to the building-slip, these have been shaped to suit their respective positions, and punched with rivet-holes: one plate answering to its neighbour in the matter of spacing of holes.

The work of shaping, punching, rolling, and bending all the other plating which goes to form the clothing for the skeleton ship, is now proceeding apace, and a visit to the machine sheds in which all the work is carried on, provides matter for surprise and wonderment to the uninitiated. Here are to be found gigantic planing machines operating upon the edges of immense plates, massive rolls imparting a uniform curve to the plate surfaces, and flanging machines giving them a sharper bend. Plates up to ¾ or 1 in. in thickness are thus manipulated in the cold state with an ease that is simply marvellous to one not accustomed to the practice of modern shipyards, or ignorant of the Titanic forces in the way of hydraulics, steam, and electricity now at the command of the shipbuilder. Punching and shearing machines, driven by their own steam engines, or, as is now more approved, by electric motors supplied with power from a distant generating station, are everywhere around. Some of these are of immense calibre, punching two holes simultaneously of 1½ in. diameter, through plates 1½ in. thick, and shearing the edges as easily as a grocer slices cheese. In others, arrangements are made whereby, with the same handling (the plates being hung from overhead cranes, and only requiring manual guidance and steadying), plates are punched along both edges simultaneously, thus

saving much time and labour. In not a few shipyards, well equipped with modern tools, and especially in those where pontoon docks, dock caissons, etc., are undertaken—the uniform spacing of the holes in such work lending itself to their use—multiple-punching machines are employed, which punch simultaneously and smartly as many as twenty-eight holes! For punching out the manholes required in the longitudinals and floors of the double bottom, hydraulic machines are quietly at work achieving what are truly Herculean feats. At one single pressure ("blow" is not the word) oval pieces, some 20 in. by 17 in., are cut out of the solid plates, the thickness in many cases being $\frac{3}{4}$ in. or 1 in.

A small but vitally important preparatory operation is also here carried on, viz. countersinking the rivet-holes; that is, drilling the edges of the holes to a bevel in plates which have to be flush or smooth-riveted together, such as are worked into the shell and decks of the ship. But for this countersinking, which in smooth riveting makes room for the swelling of the rivet-point caused by the hammering, riveting would be all but useless in shell work so far as concerns closely uniting the plate surfaces, and closing the holes permanently against the admission of water. If "snap" or round-pointed rivets were not objectionable from the points of view of watertightness, of appearance, and of interference with ships' speed, they might be in vogue more than they are for outside purposes. But they are objectionable on such grounds, and unless in the upper works, or above-water portions of large ships, they have not been

PUNCHING AND SHEARING MACHINE

PLATE FLANGING MACHINE

employed for very many years. The earliest ships, of course, were thus riveted from gunwale to keel, as was but natural in the first transitionary steps from boilermaking practice. Even now, if ships' shells could be satisfactorily riveted mechanically as steam boilers are—snap-heads notwithstanding—utility, economy, and expedition at least would justify the use of "round-heads."

But to resume the story of construction. The shell-plates are marked for punching from "templates" or thin wooden patterns, giving the position of each rivet-hole as taken from the respective situations on the skeleton ship. After shaping, punching, and curving, the plates are fitted on, one by one, in longitudinal "strakes," or bands, from stem to stern, and from the keel upwards to the gunwale. The ends, or butts, of individual plates forming the strakes were, for long, invariably fitted end-to-end, and joined with a short plate or "butt strap" placed across the joint on the inside surface—in large steamers straps being often fitted outside as well—and the whole through-riveted. This still represents the practice in the largest vessels where speed is a regulating condition; but largely taking its place in recent years, in vessels for ordinary cargo-carrying service especially, the plate-ends are lapped one over the other and through-riveted. This does away with about three-fourths of the material, and half the riveting in each butt connection, which, of course, represents a considerable saving in weight of material and cost of labour, and at the same time provides a connection which is the nearest

approach in strength to the solid plate. With this arrangement, however, owing to the projecting plate-ends, the hull surface is less smooth and sightly than in the case of interior butt-straps; but, as has been indicated, unless in vessels intended for high speed, the qualities of utility, strength, and economy outweigh any æsthetic objections.

This same remark applies to another modification on former practice which has of recent years come into vogue in connection with the plating of vessels, and of which something may here be said. This is the system of "joggling" or kinking the edges of each outside strake of plating over the edges of the adjoining inner strakes — every strake being thereby brought close to the frames or beams without any intervening "filling" pieces. Dispensing with all such "packing" throughout the hull structure, and at the same time securing an equally neat, tight, and strong job (it being well recognised that packing does not contribute to strength but is merely an addition to weight), represents in some large ships from 60 to 80 tons. The system is applicable, of course, not only to shell-plating but to deck and inner-bottom plating, and, indeed, wherever the joggling of plates to meet other plates or bars "metal-to-metal" is practicable. Many shipbuilding firms and shipowners who, from a utilitarian or æsthetic standpoint, are not quite convinced of the advantages of joggling the shell, yet resort to the practice in connection with deck plating, bulkheads, and interior work. William Doxford and Sons, Ltd., of Sunderland, were the first, about 1895, to introduce

the practice of joggling, and devised special machine-tools for its accomplishment, and the practice has spread. Other firms, in place of joggling the plating, have adopted the practice of joggling the frames and bars, the end in view being the same: the saving in weight is available for extra carrying capacity. But this, though the major, is not the only advantage, for dispensing with the packing pieces saves the labour of preparing and fitting them, and renders the riveting easier of accomplishment because of the shorter rivet required.

In manual riveting each squad of riveters consists of four members—two hammer-men, a "holder-on," and a rivet-heater. The heater, who is the junior member of the copartnery, heats the rivets to a glowing white in a portable hearth, and passes them as required to the holder-on, who, in the case of shell work, is inside the vessel. The latter inserts the incandescent rivet, point outwards, through the vacant holes, and "holds-on" a heavy back-weight to the head, while the two riveters outside, with smart, regular, and telling blows, knock down the rivet-point and fill the countersink, leaving but the suggestion of a projection past the surface of the shell.

Except in connection with the plating of shell, decks, inner bottom—all, in short, that is subject to water-pressure, where flush or smooth riveting is necessary—rivets are finished off with a semi-spherical or "snap" point, there being no countersink to fill. For this work riveting by portable hydraulic or pneumatic compression machines is almost universal where ships of any size are concerned. For the flush-

riveting required in the plating of the shell and other scarcely less vital parts already mentioned, the problem of providing suitable machine-tools and methods has long puzzled shipbuilders and machine-tool makers. Partially successful methods have been tried from time to time, with, of course, on the part of inventors, a more or less noisy "flourish of trumpets," signifying no less than the complete solution of the problem; but it is the object of this little work (written by one who, apart from professional qualifications to judge, has been at pains to ascertain established facts) to speak only of what has been accomplished, and what is of promise in the future in connection with this most vital branch of the shipbuilder's art.

The whole subject of riveting and drilling ship structures calls for pretty full treatment. The ideal ship, as a structure, would be one in which there would be neither butt nor seam, and in which at most there would be only the rivets required to bind or pin the shell to the framework. This, however, is as yet a dream of the future, although the possibilities of scientific progress in connection with electric welding are such as render the dream not altogether fantastic nor foolish! However this may be; the reduction to a minimum of the amount of riveting requiring to be done in ship construction is a desirable and highly practicable line of advancement. The use of extra long shell plates; of interior plating, flanged on the edges; and of frames of single section, as distinguished from riveted combinations of separate bars, are instances of progress in this direction. It is the firm

RIVETING BY HAND

RIVETING BY PNEUMATIC POWER

RIVETING BY HYDRAULIC POWER

conviction of many skilful and initiative shipbuilders that by reducing riveted butts to a minimum the strength of the general structure is increased, labour is saved, and the number of possible points of local weakness, and consequent trouble and danger, is reduced. In this connection, as well as in the matter of cold flanging of plate-edges to dispense with connecting angles and riveting, one of the most skilful and intrepid leaders has been Mr. C. W. Sivewright, of Furness, Withy, and Company, West Hartlepool, a firm more than once referred to herein as initiators of constructional improvements.

The hugeness of the ocean-going steamships of to-day, and the thickness of the plating which forms the shell, along the margin of the main deck, the keel, and the bilges especially, are now such that it has become almost impracticable, if not impossible, to bind the structure, save by enlisting the aid of mechanical or power riveting. The rivets which the work involves are of such length and diameter that they cannot properly, or at least easily, be closed down by hand, however skilful, willing, and powerful the hand may be. This stage of development has, of course, long since been arrived at and surpassed in connection with the construction of ponderous cylindrical marine boilers, and just as it would have been impossible to have had the high steam pressure and multi-expansion—with the resulting economy and enhanced speed at sea now common—without the powerful machine-tools in use for manipulating the boiler-plates and binding them together, so it has become more and more impracticable, if not impossible, to increase the dimen-

sions and weight of our leviathan steamships without recourse to similar appliances. Hydraulic machines had to be employed in the riveting of the double-bottom framing, intercostals, etc., and along the gunwale of the Cunard liners *Campania* and *Lucania*, and they have also been used for similar features in many other vessels built at Fairfield, Clydebank, Belfast, and elsewhere. Particularly noteworthy in this connection was the heavy riveting work achieved in constructing the huge White Star liners *Oceanic*, *Cedric*, *Baltic*, etc., by Harland and Wolff, Belfast, and equally so the more recent work done at Clydebank on the Cunard liners *Caronia* and *Carmania*. The shell-plating of these vessels ranged from $\frac{3}{4}$ inch to $1\frac{1}{8}$ inch thick, and in all 1,800,000 steel rivets were used in binding the hull of each vessel, some rivets used in the bottom being 7 inches long and weighing $3\frac{1}{2}$ lbs.

It was partly owing to the difficulties which had begun to be experienced in getting a sufficiency of riveters to undertake the very heavy class of work ruling that Harland and Wolff were encouraged, if not impelled, to make the very special provision they did make, and are continuing to make, for power riveting and drilling of material *in situ*, and for lifting and transporting machine-tools, as well as structural items, over and along the vessels under construction.

The conditions of the work of shell riveting involve the separation of the riveting or hammering portion of a machine from the bolster or holder-up, the hammering being applied from the outside and the holder-up on the inside of plating, while, on the other

hand, the conditions of the process of machine riveting require that these two portions shall be rigidly held in their relative positions; in other words, that the working strains must be self-contained in the machine. No separate holder-up being possible or practicable in compression tools, whether on the hydraulic or pneumatic principle, their use is limited to the amount of "gap," and with the increase of gap there increases, in a much higher ratio, the weight of the tools. Thus, an ordinary hydraulic riveter of 24 inches gap, designed to exert 20 tons per inch on the rivet, such as is used for the framework of ships, weighs about 12 cwt. One of 5 feet gap, such as is used in closing rivets through bottom intercostals, weighs about 35 cwt., while one of 7 feet gap, probably the largest hitherto used in shipwork, weighs as much as 5½ tons. Compression riveters, actuated by pneumatic in place of hydraulic power, are not quite so heavy, a tool of 6 feet gap weighing about 25 cwt.; but still their weight is such as to interfere greatly with facility of handling and of transport from point to point.

The Belfast firm at first provided huge moving gantries over their berths, three of these being equipped, as may be seen in the view of the *Baltic* on the stocks given as frontispiece to this book. These gantries span the berths at a great height, and are of sufficient width to clear the side uprights and staging. Propelled by hydraulic power, they traverse the whole length of the berths, carrying hydraulic riveters, punchers, electric drills, rivet-heating hearths, lamps, etc. By means of these mam-

moth appliances and the machine-tools they carried, as already indicated, the heavy plates, weighing many of them 2 to 3½ tons each, of which the great White Star liners *Oceanic*, *Celtic*, *Cedric*, and *Baltic* were constructed, were not only lifted and transported to their places, but were securely riveted therein. Over 1,700,000 rivets were used in binding the structure of the *Oceanic*, and along the sheer and bilges of the vessel where the plating was doubled, and also along the whole length of the keel, rivets of an abnormal size were used. The keel rivets were 1¼ inch diameter, many of them were 7 inches long and 3¼ lbs. in weight. Rivets in the sheer and topsides were only a little less formidable, and altogether in the topsides, bilges, keel, and elsewhere as many as 72,000 were closed by machine. The rivets in the topsides were finished off outside "round-head" fashion, and, as seen in the ship to-day, perfectly shaped and equidistant, these are far from being unsightly. The holes for receiving these rivets were drilled or rimmered, electrically, through the several thicknesses of plating, one of these thicknesses having been previously punched and made to serve as a pattern in drilling the others.

To avail themselves thoroughly, like Harland and Wolff, of the Titanic capabilities of the largest portable hydraulic and other tools, as well as of the lifting and transporting facilities for both tools and structural items, a number of other enterprising firms in Britain have installed alongside and over their building-berths steel uprights or standards supporting girders or runways, and in some cases covered-in roof-

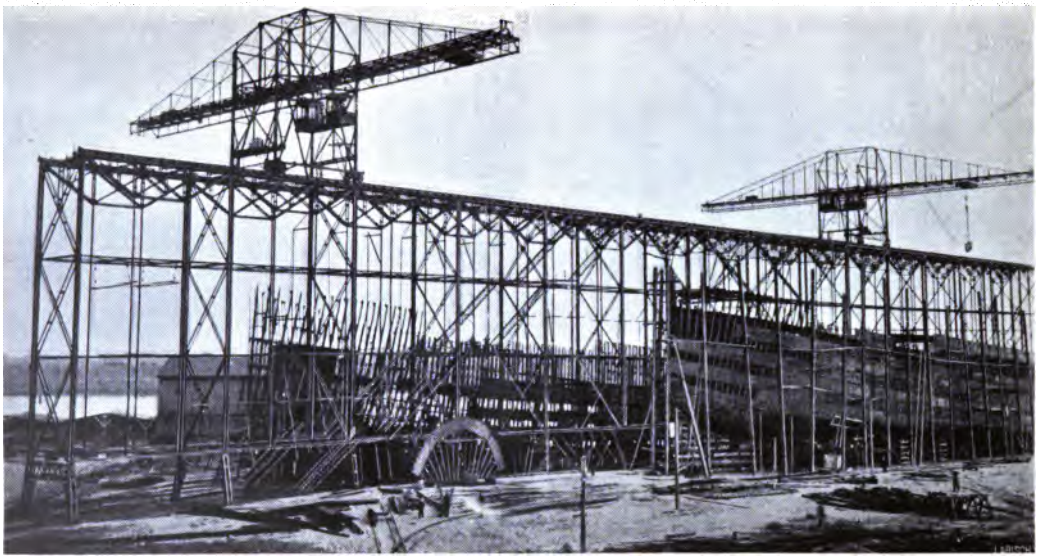
ing for shelter in inclement weather. On these runways electric cranes traverse the berths for their whole length, carrying tools and material to the points required in the vessels being built underneath. The more ordinary practice in this country is to have stationary derrick cranes of timber situated at convenient distances along the berth, the hoisting of structural items being accomplished by wire ropes and hydraulic capstans at ground-level. The newer and more elaborate system of berth equipment has been longer and much more generally in use in American shipyards, and most of the plants as yet adopted in this country are based on such as have given satisfaction there or in Germany, where they were soon installed in a number of yards; notably in the Vulcan establishment at Stettin, where the record-breaking liner *Kaiser Wilhelm II.* was constructed on a berth so equipped. Swan Hunter and Wigham Richardson, Ltd., George Stephenson and Company on the Tyne, Vickers, Sons, and Maxim at Barrow, William Beardmore at Dalmuir on the Clyde, as well as Harland and Wolff at Belfast, may be mentioned in this connection.

In the case of William Doxford and Sons, Sunderland, the crane equipment over their principal building-berths differs essentially from, and marks an advance upon, most of such equipment based on American or German practice in other English yards. The usual steel upright columns are used, and they are spanned on the Linville truss principle, under which and extending across the full width are as many as nine single tracks, each carrying three-ton electric inverted

bogies. These are used in groups of two, three, or four, as special circumstances may require, for lifting heavy weights. In addition to these, the usual radial cranes are fixed to the steel upright columns for handling all such appliances as hydraulic riveters, etc. The essential difference here is that the builders have at their disposal nine independent hooks running longitudinally, as against the usual arrangement of one or more travelling cranes with transverse trollies only.

Heavy hydraulic or pneumatic compression riveters, lifted and handled by capable power appliances, may probably long remain the most efficient, if not the only efficient, means of accomplishing the riveting work in the largest modern ships. For those of more moderate dimensions and scantling, however, machines which close rivets by percussive action—that is, by rapid and comparatively light blows—will undoubtedly hold the field; this not so much in the way of superseding as of supplementing the plant already worked on the hydraulic system. Conceivably, indeed, there may be circumstances and conditions amply justifying the use of all three power systems—hydraulic, pneumatic, and electric.

One of the drawbacks attaching to the hydraulic system as installed in open shipyards, although less so in the moderate, though by no means equable, climate of the British Isles than in many other countries, is the freezing of the water in the pipes and tools. Nothing short of charging the whole system with a non-freezing fluid has been found efficacious in meeting the exigencies of climate in many yards, both at



BUILDING BERTH CRANE EQUIPMENT IN A GERMAN SHIPYARD
Erected by Bechem & Keetman, Duisburg-on-Rhine

home and abroad. In America especially, and in Russia, Austria, and other countries, the drawback has proved more serious, and the attention of users of shipyard and bridge-building machine-tools was early directed to other power systems—notably to compressed air and electricity—and the application and perfecting of machine-tools on these systems have all along been proceeding.

Perhaps had riveting and punching been the only branches of shipyard work for which the hydraulic system is utilised, its extension, even in this country, might not have been so marked as it has been, and other power systems might have been tried and better developed. With the need, however, which arose for heavy manhole and other punching in water-ballast bottoms, and more especially with the growth in the practice of working mild steel in the cold state, the demand for heavier tools and for a greater variety of purposes, such as bending, flanging, straightening, joggling, etc., and the decided need for powerful cranes and other lifting and transporting appliances, it was found to be imperative that the hydraulic system should be developed and more and more adopted in up-to-date shipyards.

For work which can be conveniently brought to the tool, as distinguished from taking the tool to the work, hydraulic riveting, as has already been indicated, may long remain. Even for accomplishing work of the heavier class *in situ*, provided the tools can be applied at all, compression riveters, whether hydraulic or pneumatic, may long have a field of their own, as they are much more competent to bring

the materials close together than percussive tools, and they effect more thoroughly by a steady, powerful squeeze what myriads of sharp, rapid blows seem unable to accomplish so well.

Percussion riveters in their action very closely approach handwork, and by the great speed of blow, rather than by its forceful character, accomplish the work they are applied to. For this reason the outstanding characteristic and merits of the tools consist of their extreme lightness and portability. This property, of course, results in increased speed and economy of labour, and obviates elaborate and expensive holding and transporting arrangements. Being essentially hand-tools, they can be more effectively set to their work of closing down rivets which come obliquely through the holes provided, and they can be applied in restricted or awkward positions where neither compression tools nor yet ordinary hand hammers can be wielded. But a still more fundamentally important feature of the pneumatic percussive tools is that the complement of the striking part—the "holder-on"—is a practical part of the arrangement, and thus the solution of the long-standing problem of a mechanical holder-up in shell riveting is at least approximated to. For these several reasons it is not to be wondered at that a great amount of keen attention and of ready acceptance—on the part of employers, but not so much of workmen—is now being bestowed on the pneumatic percussion riveters, drills, and caulking hammers, which so far have chiefly come to us from America. In several of the largest and most modern

shipyards there—notably the Chicago Shipbuilding Company, Cramps of Philadelphia, and the Union Iron Works, San Francisco—these tools have been largely in use for some years; and in the construction of several vessels—one at least of which, the *Kroonland*, is engaged in transatlantic service—practically every rivet was driven by portable pneumatic tools. Numerous inventors have brought forward tools actuated on this system, and for a variety of purposes besides riveting and drilling; but the best known of these are the hammers and holders-on of the "Boyer" type (the drills having "Little Giant" as their trade title), and the hammers and drills of the "Haesler-Ingersoll" and "Thor" type.

Examples of all these makes of tools are now in use in many of the shipyards and boiler shops of this country, and their marvellous lightness and portability for the work done, and the great increase in its quantity in a given time, form the subject of ceaseless wonderment. The use of the pneumatic riveters dispenses with one of the four members of the ordinary riveting squad, and mere youths, or comparatively untrained workmen, can manipulate them. In cost, as well as in celerity of working, therefore, the tools are of immense advantage. It must be said, however, that in the case of riveting, caulking and chipping hammers, the penetrating din created is a concurrent disadvantage.

Only the most general idea of the mechanical arrangement and operation of these tools can be given. The pneumatic riveter comprises the two essential parts—"the hammer" and the "holder-on."

For some purposes these are detached and applied separately (for example, where the holder-on can be brought up and held close to the rivet-head by being braced against adjoining and equidistant parts of the structure), and for others they are combined by a "yoke" which renders them a self-contained machine, bearing in itself all the working strains. The hammer, though light and powerful—one make of tool weighing 22 lbs., being capable of driving 1¼-inch rivets—is short enough to go between frames, and small enough in diameter to get at rivets in corner angles. The hammer part, roughly described, consists of a cylinder, in which, by the admission of air through a very sensitive valve, a piston reciprocates and delivers an almost continuous series of blows against an outer part which forms the nose of the tool and the die applied to the rivet-points. The holder-on consists simply of a cylinder, carrying a piston, behind which air is admitted, the rod of which extends through the point-head and is cupped out to go over the head of the rivet. Secured to this cylinder is a piece of ordinary pipe, which serves to brace it against any convenient support. In some more recent tools the holder-on has associated with the air pressure a strong metal spring by means of which the holding-on cup is better kept to its work and more absolutely answers to every blow of the hammer part.

The air pressure at which these tools are recommended to be worked is 100 lbs. per square inch, conveyed from the air-compressing plant to the tools through ordinary indiarubber tubing. There is with compressed air little risk of leakage, and practically

no dropping of the pressure at tools which may be working at great heights. There are no restrictions in the way of cost or of scarcity attaching to the employment of air, save that imposed by the power of the compressing plant, and there is little or no risk of interference through frost.

The countersunk and flush-finished rivets of the shell, inner bottom, decks, etc., must be reached by riveters' hammers on one side and holders-on on the other, without any rigid connection between them. The tube conveying the compressed-air supply lends itself to this end, and by various forms of tools and holding and carrying devices easily adopted, work on these vital features of a ship can be effected. By modifying in some respects structural methods or procedure, the tools can be better utilised, and this has reached its highest stage of development in American yards. The readiness with which the pneumatic drill can be used for rimmering and making fair unsatisfactory rivet-holes in advance of the riveting operations, is a feature of the compressed-air system highly commending itself to shipbuilders. The pneumatic percussive tools, as has been stated, are as yet deficient—in the circumstances at present existing at least—in their entire ability to bring the surfaces of the several thicknesses of plating closely together, especially where curvature conjoined possibly to bad workmanship occurs. To meet the tools in this respect greater care will no doubt have to be exercised in the fitting of plates and angles by the "ship-platers," and, of course, the tools themselves may still be enhanced in calibre considerably,

without destroying their highly portable character. Probably a complete solution of the shell-riveting problem is not now far distant, but meantime the binding of the shell to the ship's framework is mostly accomplished in the old and laborious way by the "hand-and-hammer" of the craftsman.

Following upon the riveters on our imagined leviathan come the caulkers, a branch of operators whose function it is to make the plating edges and butts watertight, which is done by forcing the edge of one thickness of plating close to the surface of the other by sharp, rapid blows from a hammer and caulking chisel. In this part of shipyard work the pneumatic hammers, already referred to in connection with riveting, are found wholly satisfactory, and the rapidity and the efficiency with which the work is accomplished are matters resulting in very substantial economy to shipbuilders and owners. One man with a pneumatic caulking-hammer can easily accomplish, in a given time, as much as four men with the ordinary hand-hammer and caulking-iron, and the quality of the work is much superior. With the completion of the riveting, the caulking, and the painting of the shell, and the concurrent advance of other features in the structure—such as the deck plating, deck houses, etc., and of other branches of work in the workshops of the yard, such as deck planking, skylights, deck-seats, and the hundred and one items of deck-fittings, as well as the saloon and state-room fittings—the vessel is ready for consignment to her native element.

The work of launching ships devolves on the

carpenter branch of operatives, whose functions since the advent and universal adoption of metallic shipbuilding have of course been greatly abbreviated. The responsible and critical nature of launching, however, has grown with the growth in the dimensions and weight of modern steamships. Although not so lengthy a process, the work of launching the long and ponderous ships now so plentifully produced in our great shipbuilding centres, is quite as interesting and even more striking than constructing them piece by piece into one staunch and symmetrical whole. Many of the mail steamers and warships now afloat have weighed, when launched, from 8,000 to 10,000 tons, and in the case of the Cunard liner *Caronia*, launched from Clydebank Yard in July, 1904, the launching weight was 13,500 tons, and of the White Star liner *Baltic*, launched, at Belfast, in November, 1903—the largest vessel afloat (see frontispiece)—the corresponding weight was 15,000 tons. When loaded to her assigned draught of water this mammoth ship displaces 40,000 tons of water; this, of course, representing her total weight with cargo. To transfer such immense bodies from solid earth to the unstable and yielding sea, is certainly no ordinary undertaking, and hitches in its execution are not unknown. Ships frequently have refused to move an inch when all impediments have been removed to their passage down the ways. Nor have they yielded to the persuasive push of the hydraulic jacks, which usually form a part of the launching appliances at modern launches. Others have gone partly down the ways all right, only, however, to pull up and stick there, in

spite of all efforts to induce them to complete their voyage. So recently as October, 1903, a launching failure of this character occurred in the yard of the New York Shipbuilding Company, Camden, N.J. The steamship *Manchuria*, of the Pacific Mail Steamship Company, stuck on the ways when released for launching, and could not be moved by all available jacks, so that the completion of the work had to be postponed. There are many instances, on the other hand, of vessels slipping their leash and starting off down the inclined way on their own account. Some of these have been cases of the vessel anticipating the elaborate arrangements of the shipbuilder altogether, others have been in capricious disregard and even defiance of them. Fortunately it has been but rarely that any case of serious damage has resulted from such mischance.

Preparations for the launch of our imaginary leviathan have been proceeding simultaneously with the finishing touches to the shell. Heavy solid "standing" ways of hardwood have been laid down parallel to the keel on each side of it, about two-thirds of the vessel's beam apart, and extending into the water some distance beyond and below high-water level. A cradle of heavy timber balks is then constructed under the vessel, at the forward and aft ends principally, the bottom of which cradle is formed by the sliding-ways. The make-up of the cradle being complete, this is temporarily removed, and the rubbing surfaces of the ways, standing and sliding, are well greased with tallow or black soap. The sliding-ways and cradle are replaced and firmly secured under the vessel.

On the day of the actual launch the vessel's weight is gradually transferred from the stocks on which she has been built to the cradle and ways, this being done by "setting up" the vessel by innumerable wedges driven in between the sliding-ways and the cradle. The final touches to this work are done a short time before the actual "send-off," and when the last supporting-blocks and shores have been battered down (the setting-up enabling this to be more easily done), the vessel is "cradle-borne." By a locking arrangement of the two lines of ways—in which the "dagger" or "dog-shore," a small piece of hardwood, plays a vital part—the tendency of the ship and cradle to glide down the lubricated pathway is resisted till the proper moment. When this juncture arrives, signals are given by the shipyard manager, meaning "All clear" and "Down dagger." Following upon the latter the superimposed weight falls on the dagger and knocks it out of position. All impediment to the progress of the vessel down the ways is now removed; that is, if the careful fitting and greasing of the ways have been attended to. At the first symptom of an inclination of the hitherto inert mass to glide away, a bottle of wine is broken on the vessel's bows, and, at the same moment, it is named or "christened" by the officiating principal—usually a young lady who invariably, according to the descriptive reporter, does her part of the work "gracefully." The creation of the shipbuilder—now and for all time spoken of as "she"—glides down the appointed pathway with steady and gradually increased velocity until, amid the cheers probably of assembled spectators, she is

safely brought up by the resistance of the water, and, in addition sometimes, where launching room is restricted, by drag-chains and weights on shore.

Launching methods, of course, vary in different districts and shipyards according to the exigencies of situation, established practice, etc., but the process as above outlined represents that most commonly followed. Each ship has to be treated according to its particular requirements connected with form and weight. The size of the ways and the amount of declivity suited to each case are some of the questions which must be considered and determined beforehand. Altogether the work of launching is a highly responsible part of the modern shipbuilder's art, and the comparative immunity from serious mishap is striking testimony to the care and skill brought to the undertaking by managers and workmen. As soon as the vessel is completely water-borne, the cradle of timber in which she was carried down the ways floats asunder, and the items are towed back to the shipyard by workmen in row-boats assigned to that duty.

Though the leviathan is now "afloat in her native element," her completion is not yet. Much of the deck-work and interior fittings, especially of the joiner and cabinet-making departments, previously prepared in the shops, has to be installed. If, as in our suppositionary case, the vessel is a modern steamship, some of the iron deck-houses and casings have had to be left unfastened in order that the huge boilers, engines, and accessory parts may be hoisted on board by powerful cranes, steam or electric, some of which, recently erected, are capable of dealing with lifts

from 100 to 150 tons in weight. If the vessel is a naval ship, the topside armour, casemates, and guns form the most formidable lifts; if a sailing ship, the masts and spars are the most unwieldy items to be dealt with. Great advance in the power and manipulative capabilities of fitting-out cranes at public and private wharves has been made within recent years; and in several British shipbuilding works, where naval work is undertaken, mammoth cranes of German design and construction have been erected. Two of the illustrations in this book represent huge cranes which have been doing notable service in establishments in Germany for a number of years past; the makers in both cases being Bechem and Keetman (Duisburger Maschinenbau Actien-Gesellschaft), Duisburg-on-Rhine.

The responsibility of the engineering section of the shipbuilding establishment, which, as will be understood, has all along been concentrated on producing the propulsive machinery, and sometimes the machinery for electrically lighting the vessel throughout; for producing artificial cold, especially in vessels intended for carrying frozen meat; for actuating the bulkhead doors, as well as the winches and cranes on deck for working cargo, anchors, boats, etc., is, of course, at this juncture greatly accentuated. The engines, which have already been erected in the engine shops, are now piece by piece re-erected on their seatings, and all pipe connections accurately made between the several parts, and especially the main steam pipes to the boilers, which have also been installed and connected up; the huge iron funnels to convey the

products of combustion to the outer air, surmounting all. Preliminary, or "dock trials," with the engines, boilers, and propellers, are now made and any imperfections rectified. When at last—after the finishing touches of the painters, upholsterers, electricians, etc., have been imparted to the vessel—she steams, or is towed, out to the scene of her trials, the sense of responsibility on the part of both engineering and ship sections is little, if anything, abated.

The onerous, sometimes conflicting, conditions to be fulfilled in many ships have already been referred to. The stipulations as to carrying capability with a given speed and draught, and sometimes a given consumption of coal, or as to steaming powers in vessels of specially high speed are often most exacting. The "measured mile"—that is, the nautical mile of 6,280 feet determined by fixed marks on a straight length of coast line—is usually the means by which a vessel's speed capabilities are ascertained; but, in addition to "running the mile," most of the higher-class steamers have to undergo tests of steaming continuously over long distances at a fixed rate of revolution of the engines and propellers. Two, four, and sometimes more separate runs are made over the mile; half the number with and half against the tide, the object being to eliminate the tide's influence from the results. The mean time taken to accomplish each double run enables the shipbuilder to compute the speed per hour of which the vessel is capable. "Progressive" steam trials, that is, trials over the mile, at various powers and rates of revolution, have for many years been made by certain ship-

CANTILEVER 150-TON WHARF-CRANE AT GERMANIA WORKS, KIEL, GERMANY

Makers: Bechem & Keetman, Duisburg-on-Rhine

builders and engineers, and from the results obtained scientific analysis enables close approximation to be made to the performances of other ships of similar form, but of different dimensions and speeds. Supplementing and correcting the results from model experiments, progressive trials and investigations, in competent hands, and based on Froude's "Law of Comparison," yield most valuable results. As in the case of the experimental tank, so also in that of progressive trials, Denny and Brothers of Dumbarton were pioneers. Contemporaneously with them in this, and in other directions taking the lead, Dr. John Inglis, of Pointhouse Shipyard, Glasgow—himself a distinguished student of Dr. Macquorn Rankine's, and an accomplished investigator of scientific problems connected with engineering and shipbuilding—has done most valuable work.

Mention, here, of Prof. Rankine, and of results flowing from his profound understanding and tuitionary talents, suggests mention also of some of the agencies of education in the science of shipbuilding and engineering now operative. The Naval College at Greenwich has for many years afforded excellent fundamental training for naval aspirants; and the John "Elder" chair of naval architecture in Glasgow University (founded and endowed by the widow of the renowned engineer of Fairfield), occupied in turn by Dr. Francis Elgar, Prof. Philip Jenkins, and Prof. I. H. Biles, LL.D., its present occupant, has proved a potent factor in the shaping and equipping of ship designers and managers attaining eminence in various parts of the world.

CHAPTER IV

EVOLUTION IN STRUCTURE AND TYPES OF SHIPS

IN the course of the description of the sequence of operations involved in constructing a typical modern ocean-going ship in a representative modern shipyard, with which the last chapter was almost mainly concerned, allusion was made at appropriate places to the evolutionary development in structural details and methods of work which has been proceeding all along, but especially since the advent of steel as the building material, but much that is essential from the point of view of cheapened production and of permanent economy in after service has as yet been unnoticed.

The introduction of mild steel for shipbuilding and the improvements in its manufacture which have almost constantly gone on since, have had an incalculable influence upon the dimensions and design of ships and on structural methods and details. To the steel manufacturer indirectly a very considerable share of credit is due for the development which has taken place in the production of modern ships. While the art of the manufacturer of iron was limited to rolling plates and ordinary angles, the iron ship in

consequence was only what a combination of plates and angles could effect. The shipbuilder's limitations even in the heyday of shipbuilding in iron, and the curious makeshifts to which he was impelled, when anything out of the ordinary was involved, are matters sufficiently illustrated in iron ships which still exist. The *Great Eastern* herself, though now *non est*, disclosed at the time of her break-up in 1890 some of the limitations which even the genius of Brunel, her designer, and Scott Russell, her builder, could not but chafe at, yet which the least skilful of builders of the present day can afford to smile at. Plates, for instance, in the early days of shipbuilding in iron, did not exceed from 10 feet to 12 feet long and 3 ft. 6 in. broad, and up until the advent of mild steel the dimensions hardly ever exceeded 12 feet to 16 feet by 3½ feet to 4 feet, the standard length being 14 feet. Plates of steel now commonly used are from 24 feet to 32 feet long and 5 feet in width, while in the practice of leading yards, as we have already seen, they are often 34 feet long. But even this is exceeded in particular instances: for example, Furness, Withy, and Company, West Hartlepool, who previous to 1893 were in the habit of using 32-feet plates, were in that year supplied by the Consett Iron and Steel Company with plates 64 feet in length by 4 feet to 4 ft. 3 in. broad, which were worked into the shell of some large cattle-carrying steamers then being built. In vessels built since, for the frozen meat trade, this firm has fitted even longer plates in the midship body, viz. 67 feet long and 5½ feet wide, and weighing nearly six tons each. While on this subject reference

may be made to the "trophy" plates shown by Colville of Dalzell Steel Works, Motherwell, in the Glasgow International Exhibition of 1901, one of which measured 72½ feet long, 6 ft. 2 in. broad, and ⅛ in. thick; the other being 65 feet long by the same breadth. In the ordinary course, this firm rolls plates up to 50 feet in length, and to 11 ft. 2 in. in width. Accustomed as they long were to 32-feet plates, Furness, Withy, and Company's workmen handled the mammoth plates above mentioned without any great trouble. The fact of only one butt-joint being needed in a length of 120 or 130 feet of course means, in very long vessels especially, a considerable reduction in the amount of riveting as well as in the weight involved. Reducing the number of butts also obviates so many points of possible weakness and leakage. The adoption of lapped in place of strapped butts, and of joggled instead of plain plating, with the advantages of weight saving and reduced cost appertaining, are points sufficiently dwelt upon in last chapter.

Apart altogether from the improvements effected at the rolling mills—virtually abolishing all limitations as to length and other dimensions other than the limitations imposed by convenience of handling in the shipyard—immense advantages attach to the use of mild steel, due to its ductile character. Its superior strength, weight for weight, compared with iron, and the saving in weight of material thereby secured, as well as other accompanying advantages, are matters already commented on. There is, however, the further very great advantage attaching to steel of the

superior way in which it lends itself to being manipulated in the *cold* state. By the aid of simple, though powerful, machinery changes of form can be rapidly effected on mild steel just as sent from the makers, which with iron could only be brought about after repeated heatings in the furnace or at the smith's fire, with, of course, extra expenditure of time and labour. This is especially exemplified in the work of flanging and joggling plates, to which reference has repeatedly been made. It may here be added that the practice of flanging steel plates cold has reacted on manufacture and ensured requisite care being taken as to quality. The general result is not only that weight is saved, but that expensive riveted combinations of plates and angles are dispensed with. In brief, it would be impossible to build steel steamers for the price they are now produced at but for the advantages spoken of and others which might be instanced. Not only are ships more cheaply built than formerly, but, with the steel as now supplied, workmanship is improved and the strength at least maintained, notwithstanding the reduced scantling. Further economies still are in view, resulting from the manner in which steel lends itself to manipulation without heating. Some years ago (1897) a machine was being experimented with, and was seen in operation by representatives from some of the largest British shipyards, whose functions were to impart not only the flange bevel to frames, but to effect the proper general curvature as well, both operations being done simultaneously and with the steel frame just as sent from the manufacturers.

Should this invention, or one similar to it which is now being experimented with, eventually be perfected and receive adoption (so far as it has not made sensible progress in actual use), almost incalculable economies are bound to result, and the "art' of frame bending and bevelling will become more of a mechanical process than ever.

It goes without saying that shipowners are keenly alive to the advantages accruing from a low first cost for their ships, but the same is true regarding their appreciation of features of structural and general arrangement, which are of cumulative advantage in the working of the vessels in after service. Commercial considerations alone, especially in purely cargo-carrying vessels, have had constant and often very marked influence in modifying existing types and in bringing into vogue at different periods, according to the exigencies of trade or of tonnage and other regulations, types of a highly distinctive character. Superseding the old types of narrow three-deck vessels, for example, that known as "well-decker" came into existence chiefly between 1880 and 1890, and mainly the product of the North-East Coast of England yards. So named from the break, and the high bulwarks spanning it, between the bridge and forecastle, well-deckers were of multifarious variety, and on the whole well adapted for general work, but the "well" did not, in cases of bad weather, conduce either to comfort or safety, owing to the lodgment and retention of heavy seas, notwithstanding the presence of large freeing-ports in the bulwarks. Later examples, while retaining in a general way the

features distinguishing the "raised quarter-deck" type, have, instead of the usual main-deck forward of the bridge, a raised deck exactly the same in height and arrangement as that fitted abaft of the bridge. Advantages claimed for these vessels over the ordinary raised quarter-deck type are greater seaworthiness, increased carrying capacity for their dimensions, and suitability for light or heavy cargoes. Both the first cost and the cost of working these and other like types of vessels are, of course, their chief recommendation to owners.

Skilful and ingenious shipbuilders are constantly seeking to meet the demands for these commercial qualities in cargo ships, and not a few shipowners are able to point the way. Large and capacious cargo-holds, clear of obstruction as much as possible, and affording the means for ample and unbroken stowage, have long appealed to shipowners. Decks and tiers of hold-beams began to be omitted very early in the history of shipbuilding in steel, and the transverse strength they contributed was made up for by "web" or plate-frames at stated intervals and by side-stringers. These, however, were attended by much loss of stowage, and the arrangements were expensive to build, Thanks to the provision by the steelmakers of heavier angles than formerly, and of these sections of "bulb angle," "channel," and "Zed" bars already referred to, simpler and stronger framing than before has been rendered possible, while at the same time stowage is much less interfered with, and the requisite transverse strength is maintained. By this means and by additional bulkheads and other arrangements the

skilful shipbuilder is now meeting the keen shipowner in his desire for deep, clear holds. The forests of pillars formerly to be seen in the holds and 'tween decks of cargo vessels are now disappearing, and in the place of the many smaller ones a few very staunch central pillars are adopted for supporting beams and maintaining rigidity.

A leading part, at least as a shipowner, in introducing such features as those under notice has been taken by Mr. Alfred Holt, of the well-known Liverpool shipowning firm, whose vessels embody numerous and very ingenious modifications of his own devising or suggestion. In many of them the transverse frames are as much as 36 inches apart instead of the usual 27 inches for vessels of the size, the requisite transverse stiffness being secured by fitting frames deeper and weightier in section. The larger area of unsupported plating is stiffened either by side-stringers running the whole length of vessel, between the frames, or by having the plating itself one-twentieth of an inch thicker than in ordinary vessels. In the Holt vessels a few large central pillars take the place of the many stanchions in the holds. In a vessel of 52½ feet beam these pillars, 21 inches in diameter, rise from a stool secured to the inner bottom, and are attached to a strong box-girder connected to the deck and beams, and to the transverse bulkheads by large brackets. In these vessels, too, a very special method of supporting the propeller at the stern is adopted, involving a rearrangement of the usual framing and plating, which dispenses with the massive forging or casting ordi-

narily employed for this purpose. A considerable part of the rudder area is below the bottom of the sternpost, which is a wrought-iron tube, 1 inch thick and 21 inches diameter, and the line of ship's bottom runs up from a point forward of the aftmost watertight bulkhead to only a very short distance below where the propeller shaft emerges. For this important modification it is claimed that it is lighter, at least equally strong, and contributes to the steering qualities of the vessel.

Side by side with, or perhaps overtopping the desire for free holds and easily worked vessels, the shipowner's old longing for reductions in the net register tonnage, relatively to the size or carrying capability of their vessels, has made itself felt in recent years. In this, even more than in scheming out clear holds, much skill—not necessarily or always of a technical kind—has been evinced by obliging shipbuilders. The result is seen not only in trifling though "tricky" modifications in conventional features of the ordinary types of vessels, but in the existence of a number of types of cargo-carrying and "money-earning" craft exemplifying both technical skill and ingenuity. The best-known examples of these radical departures from conventional lines are the "turret-deckers," although numerous "trunk" steamers, as they are called, have also been brought forward by competing shipbuilders. The turret type of steamer is the production of the skill and ingenuity of William Doxford and Sons, Sunderland.

The first vessel of the type, named the *Turret*, was launched by that firm in the latter part of 1892, and

was an admitted experiment, in whose success few appeared to believe save the builders themselves and the firm of shipowners—Peterson, Tate, and Company, Newcastle—who enterprisingly gave the builders their opportunity. The outcome was awaited with considerable interest. On her first voyage the *Turret* encountered a fierce westerly gale, and at once afforded ample proof of the steady and weatherly qualities of this type of "odd-looking craft." The germ of the type may have been suggested by the "whaleback" steamer, an example of which, the *Charles W. Wetmore*, made a trip across the Atlantic to this country, and the construction of which Doxford and Sons had opportunities of studying. The term "whaleback" is almost self-explanatory, the idea of the designers being to evolve a steamer with decks clear of all erections, even of hatch-combings, so that the seas might sweep on board without doing any damage. As in navigating such a vessel the weather-deck would be altogether unsafe in a seaway, a superincumbent gangway was provided, supported on turrets built into the weather-deck. Although the "whaleback" has perhaps found a field more or less suited to its peculiarities in the cargo service of the Great Lakes, the type has not developed for ocean purposes. The modern turret-deck steamer, on the other hand, has grown surprisingly in size as well as in number during the dozen years since it was introduced. In reality, the turret steamer has little in common with the whaleback, save in two outstanding features. They resemble each other in that their gunwale or deck-edge is of

rounded form, and that they have no sheer, or deck curvature fore and aft, differing in the latter feature from all vessels of the ordinary type.

The turret steamer below the water-line differs in no way from the ordinary cargo steamer, except perhaps that the square or midship body is continued further forward and aft than is usual. Above the water-line is the "harbour" deck, beyond the outside round, and on its inner side rises, also in rounded form, the turret erection, and on the flat turret-deck are all hatches, deck-openings, and deck-houses. This unbroken line of rounded gunwale and turret erection, conforming as it does more to the ideal of strength—the complete cylinder—imparts immense strength to the general structure, and that in a very simple way as compared with ordinary vessels. The frames are carried up the side, round the gunwale and harbour-deck, and up to the turret-deck, while the same thickness of shell-plating is maintained. The idea of the inventors was not, of course, simply to put a steamer of a new and strange model on the water, but so to produce a steamer which would give a maximum carrying capacity with a minimum net register; and one possessing light draught; clear holds for the carriage of any description of bulk cargoes, as well as the more ordinary run of cargo. Extremely simple in construction, the type permits of great flexibility in design, and experience has proved that the aim of securing a large carrying capacity on small register tonnage has been achieved. The first three turret vessels, constructed to the order of Peterson, Tate, and Company, Newcastle, were em-

ployed in such dead-weight trades as coal-carrying on the St. Lawrence. These proving successful, other vessels were built to engage in different trades, and other shipowning firms began to order similar vessels. From the time of the fifth or sixth turret, in fact, Doxford and Sons have devoted almost their entire energies to turning out this class of steamer, and for one company alone, that of the Clan Line, two dozen turret ships have been built, some of them 450 feet in length, which are employed running in that company's Cape and Far Eastern trades.

Up to about Midsummer, 1904, 100 turret vessels had been put into the water, varying in size from the ordinary turret of 3,200 tons gross register to the *Grangesburg* of 6,750 tons, with a dead-weight capacity exceeding 10,000 tons on 22¾ feet draught, and with engines developing 2,200 horse-power, giving a speed of 10½ knots. The earlier vessels were for coal-carrying purposes, but the type soon approved itself for grain and other bulk cargoes, the turret erection serving well as a feeder to fill up vacancies occurring in the bulk cargo. The *Grangesburg* just mentioned was built for a Rotterdam firm for engaging in the ore-carrying trade, and the appliances for rapid discharge of ore are very special. There are twelve large hatchways, the vessel being built with six separate compartments for ore. Seven pairs of masts, each 56 feet high, are fitted abreast of each other, and carry twenty-four derricks, worked by twelve double-ended winches. Opposite each hatchway, and on both sides, are twenty-four portable platforms, upon which the ore is emptied when lifted from the hold, and thence

TURRET STEAMER IN FRAME, IN THE YARD OF WM. DOXFORD AND SONS, SUNDERLAND

it can be sent into barges through "chutes." The whole cargo of ore can be discharged in about thirty-five hours.

The list of modifications in ship design—all of them having economy, utility, and convenience as their aim—could be extended indefinitely. We only prolong the story to add that they are evinced in matters of external appearance and general outfit as well as in those of structural arrangement. The "clipper"-bowed steamer is a thing of the past, at least where cargo vessels are concerned, and the raking masts which, not so long ago, were designed with regard to smartness of appearance, as well as to bearing some spread of sail, are now mere upright poles or posts for the display of signal lights and the support of derricks and other working appliances. Indeed in the acme of up-to-dateness in the way of cargo steamers, having all the latest gear for loading, stowing, and unloading cargo, there is presented a craft sharply severed from the conventional, if not from the symmetrical and graceful as well! But, after all, merchant ships are built to meet the requirements of trade, not art; and if owners, shippers, navigators, and even harbour authorities are satisfied, who is entitled to grumble?

In all that has gone before the aim has been to deal only with the evolution and the methods involved in the production of ships of the great main classes; that is, passenger ships, cargo vessels, and—less prominently than they deserve—naval ships. Of course, embraced in these three great classes are almost innumerable sub-classes, which in a larger

work than this would be accorded some attention, but this is not essential where the aim is to convey in limited space as accurate a conception as may be of shipbuilding in its more general aspects. Nevertheless, some of these sub-classes are distinguished by features so special that they here demand at least some mention. Firstly, there is the immensely important, and structurally very special, class of vessels built for dredging purposes. On these productions, whether bucket or sand-pump dredgers, it is needless to say the development of most of the world's canals, rivers and ports, harbours and docks, largely depends; and in consequence on their number and efficiency also depends the evolution of shipping generally, but especially of the huge ocean-going passenger and cargo liners. In Holland steam dredgers were very early a special product of the shipbuilder's skill, and vessels of this class are still built there in large numbers. For many years, and to a larger extent than in any other British district, dredger building has been a speciality of the river Clyde, and almost wholly in the hands of three or four firms, viz. William Simons and Company, Renfrew; Lobnitz and Company, Renfrew; Fleming and Ferguson, Paisley; and Ferguson Brothers, Port Glasgow. These firms' productions of both the bucket and suction-pump order have been put to work in all parts of the world. Another special class of craft on which shipping so greatly counts for invaluable assistance are steam tugs of both the paddle-wheel and twin-screw type, the latter for ocean towing particularly. Oil steamers for carrying oil in bulk, ice-breaking and train-ferry

steamers, telegraph-cable laying steamers, steam trawling vessels, stern-wheel steamers of abnormally light draught, for service in remote and generally inaccessible regions of the world, and steam and sailing yachts for sport and pleasure which thickly stud the waters of our sounds and estuaries; all these, also, are classes of productions involving features special in themselves, or not common to the great general body of shipping, yet which can only here be mentioned.

In regard to naval ships, of course, a chapter in itself would scarcely afford the space necessary for mere enumeration of their distinctive types and purposes; but, after all, the main features are not materially different from those which, broadly speaking, characterise mail and passenger and ordinary merchant shipping. One exception to this, however, must be made in the case of submarine vessels, which, although hitherto only developed for warlike purposes, may eventually assume importance in the domain of peaceful transport, or of scientific exploration, if not perilous pastime; all as suggested long ago in the romance of Jules Verne. The idea of underwater navigation is, of course, very old. Fulton, of America, for example, experimented with submarine boats while in France, 1797–1801, and by the latter year, it is said, had succeeded so well with them "as to create much anxiety in the minds of the English, then at war with France" (Thurston's *Growth of the Steam Engine*). The number of inventors in this connection since Fulton's time has ever been on the increase, and experimental craft have been built from

time to time and tried with varying success in different countries, notably the United States, France, Britain, Spain, and Italy. The technical problems incidental to the design and construction of submarines, Sir W. H. White assures us, have been long studied, are well understood, and it has always been possible to produce vessels of the class if naval authorities required them. It was chiefly, however, during the latter end of the nineteenth century that submarines came much to the front as instruments of war, and it is to inventors and experiments in France and the United States that the greatest credit belongs for the measure of practically all-round success attained. The British Admiralty took no action to introduce submarine vessels into the Royal Navy until the year 1901. An opportunity presented itself of securing the result of the experience and great mechanical skill of Mr. Holland, of America—from whose designs the most successful vessels produced and tried in America were built—and arrangements were made in the year named with Vickers, Sons, and Maxim, of Barrow, who had acquired the rights of building boats on the Holland principle, for the production of five such vessels. These have been completed and put in service for some time, and orders have subsequently been given to the Barrow firm for over a dozen larger and improved vessels. This fact would seem to indicate that the earlier boats have given satisfaction, although no official reports are available. France has produced altogether some forty submarines of one type or another, ranging from 110 to 160 feet long; the United

States nearly one dozen; Italy four; Germany two, and Russia two or more, six at least being now under way. Broadly speaking, submarine vessels are all cigar-shaped, and must of course be absolutely watertight, and have respirating necessities for the crew while submerged, and for most part while proceeding along the surface of the water. Some of the French submarines, it is believed, are capable of remaining under water for twelve hours at a time without inconvenience to their crews, which practically means that they can stay at work under water all day, and only rise to "breathe" at night. For under-water propulsion electricity is the motive power generally employed, while for surface propulsion gasolene engines form the motive power most in favour. From 8 to 12 knots are the speeds attained in most of these vessels, while the last British boats, which are 100 feet in length, are stated to have done 14 or 15 knots. No authentic facts, however, are published.

Although scarcely a digression, what has been said of submarines—or vessels for under-water navigation—brings more forcibly before us our true text—the general and main line of development in building ships for service on the surface of the sea. Were not this so strictly so, attention might be given to some of the more revolutionary "new departures" in shipbuilding: so called at least, for a time, but the subsequent failure of which often justified the epithets "oddity," "freak," "monstrosity," etc., which the callous and sceptical, and of course conservative, amongst onlookers had promptly applied to them.

Ideas for submarine boats with an outer revolving hull, having projecting vanes spirally traversing the hull from end to end, and intended to "gimlet" its way through the water; "roller" boats to roll over rather than plough through the water; and "aqua-aerial" craft to skim or hop, grasshopper fashion, along the surface, part of the time on water, and part time in air. These and innumerable other notions have been proposed and, in not a few cases, experimentally tried at great cost, and, no doubt, with deplorable disappointment for the inventors and projectors. Commercial prudence and industrial caution, of course, look askance on such revolutionary projects, and, no doubt, while their failure justifies this attitude, they have, at least, the effect of illuminating and making clearer the true line of advancement; although another effect unfortunately is the retarding of true advancement, through capital being withheld from moderate, promising, and, eventually, highly successful propositions.

To return, at last, to the main line. The efficiency of triple as compared with twin-screws driven by reciprocating engines, is a matter upon which naval architects and marine engineers are even less agreed than they were when twins, in place of single-screws, were introduced. The triple-screw arrangement is, of course, no new thing, and for purposes where shallow draught or other special conditions have been the regulating factors, three and four shafts have long been used. Admiral Melville, of America, has been the great advocate of triple-screws where enhanced power and speed formed

the object in view, but he has not been fully supported in this by the naval construction department in America, and his views have not been endorsed by the great authorities in this country. Sir William H. White, for example, has not followed the lead of Admiral Melville and of other naval designers in France, Germany, and elsewhere in this matter, and the results from practice abroad would seem to support his position. Ten years ago (1895) two large American triple-screw cruisers of 19,000 horse-power each were constructed, but in later vessels twin-screws have been preferred both for battleships and cruisers up to 25,000 horse-power. Having been personally responsible for the continued use of twin-screws in the Royal Navy up to 1902, Sir William H. White, in his presidential address before the Institute of Civil Engineers in 1903, put on record the reasons for his action. One paragraph may be quoted: "At first it was claimed that triple-screws gave better propulsive efficiency than twin-screws. Having had exceptional opportunities of making a thorough and extended analysis of the actual performances of many ships, I have to state that this is not the case, the advantage, in this respect, is distinctly with twin-screws so far; and although it is possible that, with larger experience, the performance of triple-screws may be improved, and approach, or equal, that of twin-screws, it is practically certain that, under existing limitations of draught, and with reciprocating engines making the number of revolutions and piston-speeds now accepted, there is no reason why triple-screws should

be preferable to twin-screws up to 40,000 horse-power. There are many instances of distinct inferiority in triple-screw ships, and my foreign friends, who are building these vessels, admit this, urging that there are compensating advantages." These refer to the manufacturing advantages of the smaller parts in the three engines, and to the alleged economy in throwing one engine out of work when at cruising speed, with a resultant economy in fuel, but these Sir William disproves. As to the further advantage claimed by advocates of the triple-screw, viz. giving one more chance of avoiding total disablement, he says: "Large experience shows that for all practical purposes twin-screws give a sufficient margin of safety."

These remarks, it should be pointed out, have a more intimate bearing on naval ships than on mercantile vessels of great power and speed; to the latter a few words written by Sir William ten years previously, more aptly apply. The words, as quoted in the address, are: "It is reasonable to suppose that as higher speeds are attained and larger powers have to be utilised, since the limits of draught for ocean-going steamers are fixed by practical considerations, triple-screws may become necessary to efficiency." That point, in Sir William's judgment, had then been reached, and "the use of turbine engines with higher rates of revolution will also render desirable the adoption of three or four shafts, although the diameter of screws will be made relatively smaller."

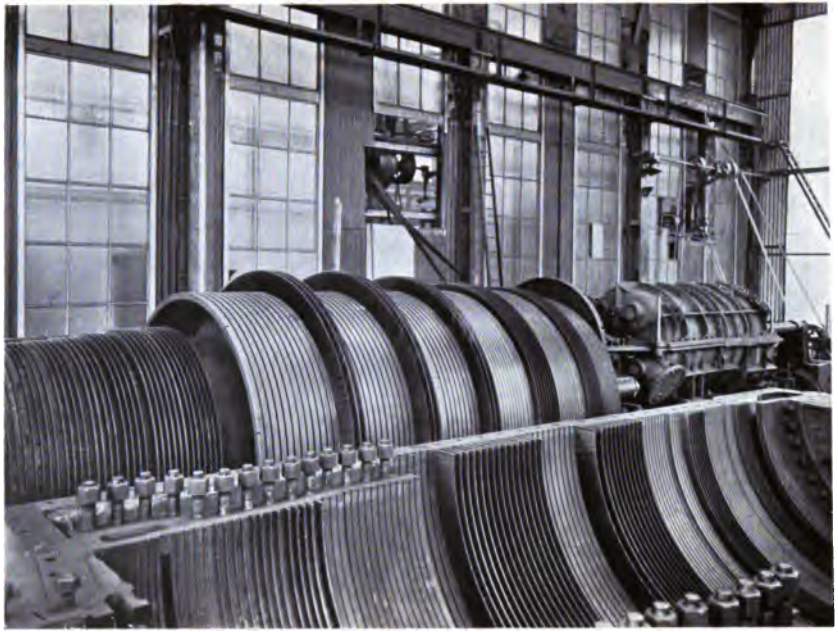
Turbine engines and three or four shafts, each carrying one or more small-diameter, fast-revolving

TURBINES FOR THE ALLAN LINER "VICTORIAN"
Under construction in the shops of Workman Clark & Coy., Belfast

screws, are even now quite the approved means of propelling high-speed river and channel steamers, and they are presently being introduced on such a stupendous scale in individual cases of ocean-going steamers of the largest and swiftest class that there seems no doubt of the "turbine era" having fully arrived, and that the fresh line of development in steam navigation will proceed at a marvellously accelerated rate as compared with its initiatory stages just a century ago. Lord Kelvin has described the invention of the turbine as the greatest advance made in steam-engine practice since the days of James Watt. In various forms, of course, crude it may be, rotary engines resembling the turbine principle have been known to science for many centuries, and some discern its prototype in the steam toy or Æolipile (or Ball of Æeolus) of Hero of Alexandria, known more than two thousand years ago. The resuscitation of the rotary system—amounting almost to re-invention—in the present day, and the constructional improvements necessary to adapt the turbine to steam instead of water as the motive power, was first developed by the Hon. C. A. Parsons in connection with the driving of electric generating plant, and it still greatly progresses in that domain.

Both in theory and design the steam turbine is one of the simplest of all motors, although in detail a clear description cannot be here attempted. Briefly and in plain language it consists essentially of a revolving shaft (in its marine application the very shafting which carries the propellers) on which is keyed a drum carrying outwardly projecting blades

or vanes, enclosed in a cylinder containing inwardly projecting fixed guide-vanes. At each end of the cylinder is a bearing in which the shaft with drum revolves, as the steam admitted into the cylinder impinges and expands against the multiplicity of fixed and moving vanes. Steam entering at one end of the cylinder passes first through a ring of fixed guide-blades, and is projected in the rotary direction on the succeeding ring of moving blades, imparting to them a rotational force. The same process takes place at each of the successive rings of fixed guide and moving blades, steam pressure falling and expansion increasing as the process goes on. Speeds of rotation of from 2,000 to 5,000 revolutions are common in the turbine motor, especially as applied to land purposes, while it is capable of running, and has actually run, at the almost incredible speed of 18,000 revolutions per minute. The bearings spoken of at the ends of cylinder are the only rubbing parts in the whole motor; there are no slide-valves, valve-gear, nor reciprocating rods and parts to wear loose, get adrift, or require attention, adjustment, and lubrication. The complete absence of reciprocating parts and the extreme smoothness of the rotary motion result in the elimination of vibration and jerk, which are more or less in evidence in reciprocating engines even of the most approved "balanced" type, although in this respect great advancement has been made within recent years. The absence of vibration, the reduced space required, and the reduction in engine-room supervision, as well as of the lubricating oils which are such a source of nuisance in the engine-room and of



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harmfulness in getting mixed with the feed-water for the boilers, are all very distinct advantages possessed by the turbine system, quite apart from the question of the enhanced fuel economy for power developed, and speed attained.

The first notable application of the steam turbine to marine propulsion was made in the *Turbinia*, a small vessel 100 feet long by 9 feet beam, modelled on the torpedo-boat class, built in 1894 at Wallsend-on-Tyne by Mr. Parsons and a small syndicate of friends. During the two succeeding years many alterations and thirty-one trials were made with the vessel, the nature of which is authoritatively described in Mr. Parsons' elaborate paper read before the Institution of Naval Architects in June, 1903. The maximum speed attained in trial with the *Turbinia* was 32¾ knots, which, however, was exceeded some time later, when a speed of 34 knots was maintained from Spithead to Southampton Water. This was on the memorable occasion of the Naval Review at Spithead in 1897, when the marvellous capabilities of the little vessel as to speed were demonstrated before the onlooking fleets. The tendency, of course, at first was to apply the turbine to vessels in which the conditions were most suitable to an essentially high-speed engine, and from the *Turbinia* the step to torpedo-boat destroyers was a short one. The matter was placed before the Admiralty in July, 1897, and the order was placed with the Parsons Marine Steam Turbine Company, Limited, at Wallsend in January, 1898, for a 31-knot torpedo-boat destroyer—the *Viper*—of the same dimensions as the usual 30-knot

vessels of this class, viz. 210 feet in length, 21 feet beam, and about 370 tons displacement, but with machinery of much greater power than was usual in vessels of this size. Sir W. G. Armstrong, Whitworth, and Company also contracted with the Turbine Company for machinery for one of their torpedo-boat destroyers, afterwards called the *Cobra*. The turbine engines of these vessels were similar to those of the *Turbinia*, but they consisted of two distinct sets of engines on each side of the vessel. There were four screw shafts in all, entirely independent of each other, the two on each side being driven by one high and one low-pressure turbine respectively of about equal power. The two low-pressure turbines drove the two inner shafts, and to each a small reversing turbine was coupled, which revolved idly with them when going ahead. The boilers were of the Yarrow water-tube "express" type, and these, with the auxiliary machinery and condensers, were as usual in such vessels, but somewhat increased in size to meet the much larger horse-power developed. Two propellers were carried on each shaft, and in the *Cobra* three propellers on each shaft were subsequently adopted. The *Viper*, with full-trial weights on board and a displacement of 370 tons, attained a mean speed of slightly over 36½ knots on a one hour's full-power trial. This represents nearly forty-two statute miles per hour and a power developed of about 11,500 I.H.P. Her guaranteed speed astern of 15½ knots was realised, and at all speeds there was almost a complete absence of vibration. The deplorable loss of both the *Viper* and the *Cobra*—

which in no way was attributable to the fact that they were propelled by turbines—meant the total loss of the only two sets of turbine machinery extant at that period (other than the original *Turbinia*), and this, together with the great delays in connection with carrying through torpedo-destroyer contracts, and the difficulties and expense incidental to the introduction of a radically new class of machinery, had a detrimental effect on the movement so far as this class of boat was concerned.

The attention of the owners of fast passenger river and channel steamers had, however, been directed to the advantages of turbine engines in this class of vessel, and in the spring of 1901 Captain John Williamson, Glasgow, in association with Wm. Denny and Bros., Dumbarton, as shipbuilders, and the Parsons Marine Steam Turbine Company, as engineers, arranged for a vessel 250 feet long, 30 feet beam, and about 6 feet draught of water. The outcome of this was the Clyde river steamer *King Edward*, put into service during the 1901 season, and the first passenger vessel to be propelled by steam turbines. These are similar in construction to those of the *Turbinia*, and consist of three turbines, one high-pressure driving a central shaft, and two low-pressure driving the side shafts. The central shaft carries one propeller, and the side shafts each two propellers, one about 9 feet in front of the other (subsequently, after one year's service, each line of shafting was fitted with only one propeller). When going ahead all three turbines are actuated in the same direction, but for going astern and for

manœuvring purposes a reversing turbine is fitted in the exhaust casing of each of the low-pressure turbines. Both for speed with economy, for manœuvring power, and especially for the highly appreciated quality of steadiness and complete absence of vibration, the *King Edward* was immediately a distinct success. On the measured mile in June, 1901, a mean speed of 20½ knots was recorded, the estimated power developed being 3,500 I.H.P. The average sea speed on the run of about 160 miles to Campbeltown and back in the 1901 season was 19 knots, and the average coal consumption 18 tons per day, or 1·8 lbs. per equivalent indicated horse-power per hour. It has been publicly stated by a member of the engineering firm of Denny and Company that had the *King Edward* been fitted with twin, triple-expansion engines of the most improved "balanced" type, and of such size as would consume all the steam the existing boiler could make, the best speed that they could possibly have obtained was 19·7 knots as against the 20½ knots attained by the turbine *King Edward*. The difference between 19·7 knots and 20½ knots corresponds to a gain in indicated horse-power in favour of the turbine steamer of 20 per cent. The second turbine passenger vessel, the *Queen Alexandra*, was built in 1902 by Denny and Brothers for the same proprietary as the *King Edward*, being 20 feet longer than that vessel, 2 feet broader and 6 inches greater draught, and her machinery similar to but more powerful than that of the *King Edward*. The new vessel attained on trial the mean speed of 21·63

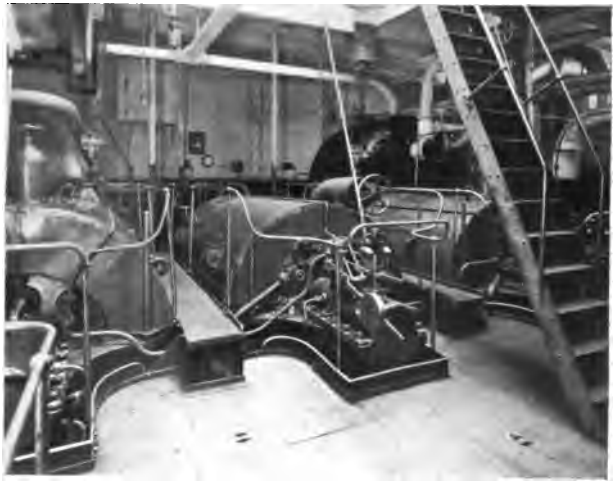
knots, and she has since given the greatest satisfaction in service on the Clyde estuary.

The success of these two Clyde vessels promptly led to the adoption of turbines for new cross-channel steamers for service between Dover and Calais, and between Newhaven and Dieppe, which Messrs. Denny undertook to build; the introduction of which, and their subsequent success, constituting a highly important step in advance in marine steam turbine machinery. The *Queen*, for the Dover and Calais service, is 310 feet long, 40 feet beam, and 25 feet deep, and when tried on the measured mile on the 12th of June, 1903, the mean speed of 21¾ knots was attained, which was considerably over the speed guaranteed. When steaming continuously astern the mean speed of 12·95 knots was obtained, and the stopping and starting trials were also eminently satisfactory. The Newhaven-Dieppe vessel, the *Brighton*, soon followed, and on service she has also well justified herself.

At a time when there was still doubt as to the efficiency of the turbine system in vessels subjected to heavy seas, the Midland Railway Company decided to adopt turbines on some of the vessels required for their new mail and passenger service between Heysham on the Lancashire coast and the North of Ireland and Isle of Man. Messrs. Biles, Gray, and Company, naval architects, were consulted, and in 1903 four vessels from their designs were ordered, two of which it was resolved should be fitted with turbine and two with reciprocating engines; an arrangement which, from the point of view of engineering science at least, seemed likely to prove most beneficial. The

four sister vessels, all of which were completed and in service during 1904, were the *Antrim*, built by John Brown and Company, Clydebank; the *Donegal*, by Caird and Company, Greenock; the *Londonderry*, by William Denny and Brothers, Dumbarton; and the *Manxman*, by Vickers, Sons, and Maxim, Barrow-in-Furness. The two latter are the turbine vessels, the machinery in which was supplied by the Parsons Marine Steam Turbine Company, while the reciprocating engines of the two first named were made by the respective builders. Two of the illustrations in this book—facing this page—show the engine-room of the *Manxman*, which, as typical of the engine-room on turbine steamers generally up to date, will interest all who are familiar with the ordinary engine-room on board ship. Comparison of the two systems of propulsion was made by the designers of the vessels in conjunction with the Midland Company's engineers, this being chiefly based on results from trials with the *Donegal* and *Manxman*, these two vessels being even more closely analogous than the other two, and the carefully ascertained results have led—with similar investigations in other cases—to a more positive conclusion as to the relative merits of the two systems of propulsion in regard to weight and space involved, prime cost, propulsive efficiency and, to some extent, the cost of upkeep.

Owners of steam yachts were not slow to recognise the advantages of turbine engines as applied to this class of vessel, and in 1902–3 three were produced. The first to be launched was the *Tarantula*, built



ENGINE-ROOM OF MIDLAND RAILWAY COY.'S TURBINE STEAMER "MANXMAN."

from the designs of Cox and King, London, by Yarrow and Company, on the Thames, for Colonel McCalmont, of 25·36 knots speed; *Lorena*, built by Ramage and Ferguson, Leith, for Mr. A. L. Barber, New York, 253 feet in length, and of 18 knots speed; and the *Emerald*, built by A. Stephen and Sons, Glasgow, for Sir Christopher Furness. The latter vessel, 198 feet long, and of about 900 tons displacement, was from the designs of Mr. Fred. J. Stephen of the builders' firm, and was the first vessel propelled by turbines to cross the Atlantic. Fitted with one propeller on each of three shafts, she attained a mean speed of 15 knots on trial, and in crossing the Atlantic at the end of April, 1903, she experienced very severe weather and head winds, but the propellers never raced, and the machinery worked with the greatest smoothness and without the slightest hitch. In some of these yachts, too, it has been demonstrated that turbine engines can be run at moderate speeds with economical coal consumption; a point, of course, which has a most important bearing on the general adoption of the turbine system in cargo and other mercantile steamers. Following the yacht *Emerald*, the Atlantic was crossed in May, 1904, by the *Turbinia*, a vessel of 260 feet in length and 17½ knots speed, built by Hawthorn, Leslie, and Company, on the Tyne, to the order of Canadian owners for service on the Great Lakes, and fitted with turbines, driving triple shafts and propellers, by the Parsons Marine Steam Turbine Company.

The Admiralty, also, had never lost interest or belief in the turbine system of propulsion, and they

purchased, in midsummer, 1903, the torpedo-boat destroyer *Velox*, built by Hawthorn, Leslie, and Company for the Parsons Company, and turbine engines were soon after fitted in another vessel of this class, the *Eden*, and in a third-class cruiser, the *Amethyst*, built at Elswick. The *Eden*, guaranteed to accomplish 25½ knots, has on a four hours' full-speed trial, with over 125 tons of load on board, averaged nearly 26⅓ knots. The *Amethyst* was put through an exhaustive series of trials by Admiralty officials in October–November, 1904, and a comparison of the results with those of three other vessels of identical design, but propelled by ordinary reciprocating triple-expansion engines, established not only her superior speed and economy at the maximum powers, but what was more interesting and impressive, the truth of what is above said to have been demonstrated by some turbine steam yachts, viz. the superior economy of the turbine system when run at only ordinary moderate speeds. When running at 20 knots the turbine ship required 30 per cent. less coal and steam than her reciprocating sisters; at 18 knots, the saving was something like 20 per cent.; at 16 knots, about 10 per cent.; while at 14 knots the consumption was about equal. At lower speeds than 14 knots the other ships had somewhat the advantage; but with experience and possible improvements in the auxiliaries in turbine engines the comparison may soon be in favour of the latter, even for merchant steamers of speeds below 14 knots. Other naval powers than our own also evinced at an early stage keen interest in the

Parsons turbine system, and grants were made wherewith to install and try the engine in actual vessels in America, France, and Germany.

Steam turbines of other than Parsons' design are now, of course, being brought forward for adoption in marine propulsion, and while some of these enjoy high repute for electric driving and other purposes on land, their application to sea-going purposes will doubtless entail—as it certainly has entailed in Mr. Parsons' case—a period of expensive and, perhaps, discouraging experimental trial and error. While the Cunard Company and other bodies concerned were in 1903-4 still being advised by a commission of experts in marine engineering and naval architecture as to the suitability of the steam turbine for the propulsion of the two proposed new State-aided Atlantic liners of 25 knots speed—the orders for which were only definitely placed in May, 1904—some ocean lines had already fully assured themselves of the economic and other advantages of the Parsons turbine system of propulsion. The Union Steamship Company of New Zealand, in September, 1903, placed with Denny and Brothers an order for a steamer, to be propelled at 18 knots speed by Parsons turbines, for their passenger and cargo service between Australian and Tasmanian ports. The Allan Line, a month or so later, determined to adopt turbine engines in a 17-knot steamer then building by Workman, Clark, and Company, Belfast, for their Liverpool and Canadian service, as well as in a duplicate vessel which they ordered from A. Stephen and Son, on the Clyde.

The Union Company's vessel—the *Loongana*, of

300 feet length and 2,500 tons displacement—was completed in August, 1904, and on the measured mile attained a mean speed of 20 knots, being two knots over what had been guaranteed. She has three lines of shafting, with one propeller on each shaft a little over five feet diameter. On trial, the revolutions averaged about 200 per minute, the I.H.P. being about 6,000. Her voyage to Melbourne in September, 1904, was accomplished in 37 days, or, deducting time lost in coaling, 30 days. Her average speed over the whole voyage was 16·5 knots, and her average daily consumpt of coal 65 tons. This works out at 1·6 lbs. per I.H.P. It is computed that in a similar vessel with ordinary triple-expansion engines the consumpt would have been 1·85 lbs. per I.H.P. Besides the *Loongana*, the Dumbarton firm—with whom the honour of pioneering the turbine system for river, channel, and coasting vessels so largely rests—completed during 1904 other six turbine vessels, four of these, of about 17 knots speed, being for the British India Steam Navigation Company's colonial service. Orders for channel steamers and steam yachts, having Parsons turbines, were placed during 1904 with various British firms, notable amongst these being the channel steamer *Viking*, for the Isle of Man Steam Packet Company, with Sir William Armstrong, Whitworth, and Company; the steam yacht *Albion* for Sir George Newnes, from designs by Sir W. H. White, with Swan Hunter and Wigham Richardson on the Tyne; and the *Narcissus* for Mr. E. M. Mundy with the Fairfield Shipbuilding Company on the Clyde.

The Allan turbine liners—the *Victorian* by Workman, Clark, and Company and the *Virginian* by A. Stephen and Sons—have now both been completed (March, 1905) and put through their trials on the Clyde most successfully. They were designed to maintain—even with reciprocating engines—an average sea speed of 17 knots, which means a 5½ days' voyage from Moville to Rimouski, the Canadian mail station. With triple turbine machinery from Parsons' design, made by the builders and by Parsons Company respectively, both liners have attained, on the measured mile, with an estimated I.H.P. of 12,000, an average speed of something over 19 knots, and have thus demonstrated their ability to maintain on the Atlantic the stipulated average of 17 knots.

The power to reverse turbine-propelled steamers has all along been a subject receiving attention from critics and doubters of the all-round efficiency of the system, and in connection with these pioneer ocean-going mail and passenger steamers the subject has been more keenly canvassed than before. Notwithstanding statements as to special provision having been made for this important function in the machinery of these vessels, the arrangements actually adopted are the same as those which have served so satisfactorily in the case of turbine-propelled channel steamers, where reversing and manœuvring capabilities are even more important than in swift ocean liners. The astern turbines are placed in the exhaust casing of each of the low-pressure turbines, and when manœuvring steam is admitted into the low-pressure turbines, or the astern tur-

bines, for going ahead or astern as may be required, independent of each other and of the high-pressure turbine. The power of the astern turbines for quickly stopping a vessel was seen when the turbine steamer *Queen* was stopped in two and a half times her own length when going at a speed of 19 knots. The illustration facing this page shows the *Victorian* on the stocks at Belfast just before launching, while those facing pages 154 and 156 give some idea of the construction of his turbines. It is worthy of note that in intrepidly committing themselves to the turbine principle on so large a scale, both the Allan Line and the Union Steamship Company of New Zealand are acting up to their traditions, their pioneering the use of steel for ocean-going vessels having been already noticed.

While, however, these companies, more, perhaps, than the firms and individuals preceding them in building turbine-propelled vessels for river and channel services, and for pleasure purposes, are to be congratulated upon the courageous enterprise shown, it will, of course, be understood that the problem which the Cunard Company has so intrepidly taken in hand—aided by the commission of experts—is one of much greater difficulty. It is one thing to design turbines to drive a 12,000-ton ship at, say, 17 knots; but to propel a 20,000-ton ship at 25 knots is a more intricate and onerous undertaking. The high importance and far-reaching character of the subject will justify a little more elaboration here. To obtain the contract average speed of 24½ knots across the Atlantic, in fair and foul weather, it is

ALLAN LINER "VICTORIAN" ON THE STOCKS AT BELFAST

believed the new vessels must be capable of a maximum speed of at least 26 knots. In matters of speed it is the last and not the first knot which costs. For example, in one of the 23-knot first-class cruisers recently built for our Navy the result of trials showed that at 15¼ knots the power required was 4,900 I.H.P., and the coal per 24 hours 110 tons; at 22 knots the power was 16,400, and coal 350 tons; and at 23¾ knots the power was 22,770, and the coal 490 tons. Thus, to increase the speed 6¾ knots—from 15¼ to 22 knots—required an augmented coal consumption, per 24 hours, of 240 tons; while to increase the speed 1¾ knots further meant the consumption of 140 tons additional. To put it in other and more concise terms: to increase the speed by a little over 50 per cent. required an increased coal consumption of no less than 400 per cent. Another interesting example of the cost of high power and speed is afforded by the trials of the scout *Sentinel*, built by Vickers, Sons, and Maxim. Designed to steam 25 knots at sea, this vessel, when tried on the Clyde in February, 1905, averaged 25¼ knots, a speed never before attained by any vessel larger than torpedo-destroyers. The trials included extended runs from 10 up to 25 knots, and it was found that to increase the speed from 22½ to 25 knots involved the doubling of the power required for the lower speed. Again, the last knot—that is, the advance from 24 to 25 knots—involved the expenditure of one-quarter the maximum power, which was 17,500 I.H.P., and the same proportion of power was found sufficient to drive the vessel at 19 knots.

With reciprocating engines it is practically impossible to employ more than three sets of machinery for driving three lines of shafting to transmit the power developed to the propellers, and the power required in the case of the Cunard leviathans is so enormous as to render it extremely doubtful whether it would have been practicable, economical, or safe to entrust each shaft with the onerous duty. The shafts, it has been computed, would require to have had 30 per cent. more strength than the strongest now in use on board ship, and to have met this by increasing the diameter would have involved difficulties in manufacture and disadvantages in working. The Atlantic record-holder, *Kaiser Wilhelm II.*, for example, embodies all the latest improvements which engineering science has devised for reciprocating engines, and the technical advisers of the companies owning her and other record-holding German-built Atlantic liners have most positively declared their belief that these vessels, with their average speeds of 23 to 23½ knots, represent the limits of speed in ocean travel commercially justifiable; for to develop a speed of 24 knots would necessitate 63,000 I.H.P., and of 25 knots 100,000 I.H.P. The *Kaiser Wilhelm II.*, with reciprocating engines of the quadruple expansion type, driving two lines of shafting, has crank-shafts, each consisting of six parts coupled together, making 72 feet in length, and weighing 114 tons; the material employed being nickel-steel. The whole range of shafting has a length of 233 feet and weighs 230 tons, the total for the two lines being 466 feet of shafting, weighing 460 tons. In the case

of reciprocating engines of such prodigious power, and consequent heavy calibre, as would thus appear to have been absolutely necessary for the new Cunarders, vibration would probably have been enormous, in spite of efforts at added weight and increased rigidity of hull structure. With turbine machinery, on the other hand, four or even five shafts might readily be employed, thus reducing the power to be transmitted per shaft. Owing also to the increased speed of revolution their diameter and weight would be less per unit of power transmitted. The saving in weight on the whole engine, shafting, and propellers, is, of course, one of the outstanding advantages of the turbine principle; while the reduction in the engine-room staff is also an immense economic advantage.

Coming now to speak of matters as they have been absolutely determined upon in connection with the huge Cunard liners. With the greatly increased dimensions which have been found necessary to fulfil the conditions embodied in the agreement between the British Government* and the Cunard Company it would have been mechanically possible—if commercially not quite advisable—to have fitted the vessels with reciprocating engines, driving three lines of shafting and propellers. It may be gathered, however, from the conditions above indicated that

* Briefly stated this practically amounts to a guarantee of interest on the money—about 2½ million sterling—required for building the two vessels, on condition that they will be "capable of maintaining a minimum average ocean speed of from 24 to 25 knots an hour in moderate weather," and will be at the disposal of the Admiralty and other departments as merchant cruisers and for other maritime service.

the fitting of suitable reciprocating engines in vessels of such unprecedented size and speed would have entailed experimental features possibly no less difficult to solve than the problems to be faced in electing to use turbines. The dimensions determined upon as requisite for the new vessels — unprecedented, of course, in the annals of shipbuilding—are: Length 780 feet, and breadth 88 feet; while the draught has been increased in measure consonant with the increased dimensions and weight of structure, and with the maximum capacities as to depth of water at the terminal ports. The displacement, even although no cargo be carried, will be between 32,000 and 33,000 tons at the outset of a voyage. To attain the average speed contemplated, at least 70,000 I.H.P. will have to be developed; and some measure of the cost at which this power will be attained is conveyed by the fact that the coal consumpt will exceed 1,000 tons per 24 hours.

After thorough and prolonged consideration and scrutiny of all aspects of the subject, as well as experimental inquiries made on models, and investigations of results from vessels already fitted, the commission of experts unanimously recommended to the Cunard directors the adoption of steam turbines applied to four shafts, each carrying a single screw. This the directorate resolved to adopt, and orders were eventually placed, in April, 1904, for two vessels of the dimensions and power above outlined: one with John Brown and Company, Clydebank, and the other with Swan Hunter and Wigham Richardson, on the Tyne. The turbine machinery

for the vessel building by John Brown and Company will be furnished by the builders, and for the Tyne-built vessel by the Wallsend Slipway and Engineering Company, supervision and advice in both cases being given by Mr. Parsons, whose system, of course, is the one adopted.

The stupendousness of the step, especially in the absence at the time of anything like actual experience with the turbine system in ocean-going steamers, was subject of doubting comment even on the part of expert engineers, and this was on the whole not unnatural, considering that the advance implied in the adoption of turbines of such immense power for ship propulsion is equal to that which it has taken over forty years to effect with the reciprocating engine. Justification for the step, however, was amply found in the result of the elaborate investigations of the commission, and in the acumen and skill of the members composing it, as well as in the subsequent experiments conducted by the two renowned firms entrusted with the construction of the vessels. Experiments with large-scale models were made to determine the best form of after body, the best position for the four propellers, relatively to each other and to the shell of the ship, and the best mode of supporting the shafting and propellers beyond the general contour of the hull. The turbines actuating the two outer or "wing" lines of shafting, it is understood, will be high-pressure, and those actuating the two inner shafts low-pressure; while powerful reversing turbines will be associated with the latter. The two inner shafts will extend much further aft

than the two wing shafts, and will virtually correspond to the ordinary twin-screws with the "deadwood" of the ship between them cut away. The turbines are being so proportioned as to moderate the revolutions to about 140 per minute, enabling propellers to be used of such size and pitch as will secure efficiency in a heavy Atlantic seaway. The installation of cylindrical boilers, worked under Howden's forced draught, will be in separate sections, and four funnels will carry off the products of combustion. The illustration facing page 160 affords a good idea of the external appearance of the coming leviathan Cunarders when finished and afloat, while the folding sectional elevation, at end of book, conveys a graphic conception of the whole interior economy of the *Caronia*, and justifies the inference that the Cunard Company, with their great experience and desire to please their patrons, are arranging for steamships as perfect as possible from the habitable as well as the structural and mechanical standpoints.

The onerous and exacting task of constructional design of these huge vessels having been gone into concurrently with the inquiries as to propulsive power, the actual work of construction is at the moment well forward in the yards of both building firms. With steady progression the launching stage should be reached some time in the autumn of 1906, and the completed "greyhounds" are intended to be fully equipped and approved for service by the beginning of the 1907 Atlantic season. In the interval several notable turbine mail steamers will have been put into regular service, and accumulated

experience and the results of study of these vessels' performances will doubtless afford guidance in the perfecting of details and accessories in the machinery of the 25-knotters. Not only will the results from actual service by the Allan liners *Victorian* and *Virginian* be at disposal, but even more apposite evidence will have been yielded by the advent and performances of the turbine Cunard liner *Carmania*, launched in February, 1905, from Clydebank, and presently being fitted with her machinery.

The decision to fit turbines into one of the two intermediate liners, which the Cunard Company ordered from the Clydebank firm before the placing of the larger vessels, was both prudent as a half-way step to the bolder advance and it will, as has been said, afford very valuable help and assurance to that goal. The *Caronia* and *Carmania* are sister ships (length 675 ft., breadth 72 ft. 4 in., depth 43 ft. 9 in.) in all essentials save that of propulsive machinery, and their comparative performances will assuredly shed most conclusive light on the all-round efficiency of the turbine principle in ocean-going steamers. The two Allan turbine liners, although also sister ships, are smaller, of less speed, and have had different builders and engineers. In consequence they do not afford so indubitable a means of testing and comparing the new type of machinery with the old. The *Caronia* is fitted with quadruple expansion engines, driving twin screws; while the *Carmania* is to have triple screws, driven by three separate Parsons turbines. The only difference in the form of the hull is that at the aft end, rendered necessary by the

three shafts. The centre shaft is to be driven by a high-pressure turbine, and each of the side shafts by a low-pressure one, having a go-astern turbine associated with it. The boiler pressure in the *Carmania* will be 195 lbs. instead of the 210 lbs. in the *Caronia*, and the turbines will take steam at an initial pressure of 165 lbs., as compared with 200 lbs. in the machinery of the *Caronia*. The area occupied by the *Carmania's* turbine machinery is about the same as that required for the engines of the *Caronia*, but there will be a saving in weight of about 5 per cent. The turbines, which have been made at Clydebank, and are now being installed in the vessel there, are the largest marine turbines yet made.

One other great influencing factor in the future of steamship propulsion, which although not thoroughly ripe for consideration as concerned with transatlantic mail steamers, yet received careful study on the part of the Cunard Commission, is the adoption of liquid in place of solid fuel. This is a matter which has received great attention from many engineers and owners for a number of years, and oil fuel, particularly in the boilers of vessels specially built for and engaged in the bulk oil-carrying trades, has received extensive adoption. In naval ships also, in this and other countries (America and Russia especially), oil fuel has been very extensively experimented with, and decided progress attained, although the production of smoke as a consequence of its use is still found to be, in naval vessels, a serious disadvantage. The advantages which oil possesses over coal on board ship are most undoubted and generally

TURBINE CUNARD LINERS OF 25 KNOTS SPEED, PRESENTLY BUILDING ON THE CLYDE AND TYNE

recognised. It can, for example, be carried in the double bottom and in the peaks or narrow parts of the vessel, at stem and stern, ordinarily vacant or used for water ballast; thus leaving the spaces now occupied by coal fuel free for profit-earning cargo. The facility also with which oil fuel can be run into, and taken out of, the storage spaces and sprayed mechanically into the boiler furnaces admits of a very substantial reduction in the staff of firemen and trimmers. In the case of one vessel of the Shell Transport Line, which, when using coal, required thirty-two men in the stokehold and bunkers, the use of oil enabled the staff to be reduced to eight only. The heating value of the oils mostly as yet employed is, roughly speaking, 40 or 50 per cent. better than that of the best navigation coal; so that a ton of oil, petroleum, say, is as good for steam raising as two tons of coal. Two tons of coal, moreover, occupy about 84 cubic feet in the vessel, while a ton of liquid fuel only occupies 45 cubic feet. Taking an Atlantic liner of 40,000 horse-power, carrying, say, 3,700 tons of coal, about 2,500 tons of oil should suffice, and 1,200 tons could be added to freight-earning capacity, besides the saving on cost of labour. On this subject, as concerned with the new Cunarders, Sir W. H. White, who was a member of the Commission, has written: "To produce the required speed in the new ships, fully 1,000 tons of coal per day will have to be transported from bunkers to furnaces, there placed upon the fire-bars by trained stokers, and burnt in the most economical and efficient manner. Had oil fuel been available, considerable economies

in weight of fuel would have been possible; and there would have been very large savings on staff and labour in the stokeholds. This matter, of course, received most careful consideration; and the decision to design the boilers for using coal was not reached until all the conditions of the problem, including the supply of oil fuel, had been investigated. Should it become possible, hereafter, to ensure adequate supplies of oil fuel at such rates as would permit of its use, it will be a simple matter to suitably adapt bunkers and furnaces."

Apart from its recognised practical utility and economies, commercial questions and the question of adequate supplies are still limiting conditions to the extended general adoption of oil fuel. This is about as true now as when oil fuel on any scale began to be employed; that is, away from the natural sources of cheap supply, such as the Black Sea region, where petroleum refuse is much the cheaper fuel, and, of course, in vessels engaged in the oil-carrying trade. Even with adequate supply assured, there still remains the question of how oil fuel may be distributed and put at the disposal of vessels in all parts of the world, at least as effectually as coal now is, although doubtless oil stations could in time be made as convenient as coaling stations; oil, indeed, lending itself to being taken on board from supply ships alongside, even when under way at sea!

Only a few brief facts as to the extent to which oil is already used for fuel, and the methods employed in using it, need here be given. In burning oil fuel in marine furnaces it has to be injected into the

furnace in the form of a fine spray. Steam has for years been employed for this, but the advantage gained is largely discounted by the fact that the steam used is lost, and the boiler feed-water has to be made up by the use of large and expensive evaporating plant. But in more recent systems steam is not employed at all, the fuel being sprayed into the furnace by means of jets of compressed air carefully filtered and heated. Two systems of this description which are now being very successfully introduced are the Korting and the Howden system. The former has been put to practical tests and perfected by the Wallsend Slipway and Engineering Company, Newcastle, who have led the way in the application of oil fuel in merchant steamers, between eighty and ninety vessels having in recent years been fitted for oil fuel by them. The latter is the apparatus devised by Mr. James Howden, whose name is so inseparably associated with the principle of forced draught as applied to the boilers of both mercantile and naval steamships. It is in association with the Howden patent hot air forced-draught system that the oil apparatus is employed. In fact, it is a combined system of oil and coal-burning forced draught: one of its chief advantages—apart from those due to no steam being used for spraying, and the economy and absolute noiselessness in consequence—is that it can be changed at sea, from oil and coal-burning forced draught, in a very short time, and without stoppage of the ship. Coal can be burned in one furnace and oil in another of the same boiler at the same time, and steam pressure can thus be kept up during the operation.

Present-day development in shipbuilding and marine engineering, broadly speaking, proceeds along the main line represented by increased dimensions; higher power and speed, attained by the use of steam generated in apparatus distinct from the engines; as well as by numerous and varied economies. At the same time, and now more than ever before, the possibilities of modern science inspire many with dreams of, and assiduous endeavour after, astounding innovations and "new departures." This, no doubt most fascinating, aspect of the general subject can only be briefly referred to. Electrical energy, now so potent a factor in the internal economy of ships, especially as regards their lighting, has for a good many years led to speculation on the possibilities of its being introduced into ocean-going vessels for their propulsion. For this purpose electricity has already met with considerable success in small craft and for very short runs, but the excessive weight of the machinery requisite for developing energy, as well as other obstacles, have so far stood in the way of progress with it in large-powered ocean-going vessels on voyages of any duration. With the continued study and experiment on the part of electrical engineers towards producing storage batteries of great capacity for their weight, the probabilities of advance are, however, not so remote.

Any means by which the present necessity for carrying in the body of the ship raw fuel—coal or oil—could be dispensed with—thus dispensing, of course, with steam boilers as well—is naturally

an alluring prospect for ingenious minds. Engines in which not only the power is generated, but combustion itself takes place, are, of course, looked to, very hopefully, in this connection. Oil motors of various kinds have received very extensive adoption within recent years in launches and small swift vessels, and the remarkable results obtained recently in motor cars, as regards lightness in proportion to power of engines, and small weight of fuel in proportion to distance traversed, have imparted additional incentive to the ingenious to apply similar motors to small vessels, with, as a result, the attainment of very high speeds indeed. For example, a motor launch, 40 ft. by 5 ft. beam, built to special design by Yarrow and Co., and fitted with two "Napier" petrol four-cylinder motors driving two screws, during a trial on the Thames in February, 1905, attained a speed of 26 knots—equivalent to 30 miles an hour—this being the very highest velocity ever reached by a vessel of her small dimensions. Mr. Yarrow has said that had he been asked to put the latest steam engine and boiler into this boat he would not have guaranteed a greater speed than 16 miles an hour. It may be taken, therefore, that the adoption of the internal combustion engine in place of a steam engine and boiler, for a vessel of this size, really represents an additional speed of 10 knots.

But it is to the progress made within recent years with gas engines of greatly enlarged power that the highest speculative interest attaches in connection with the substitution of gas or other internal combustion engines for those using steam on board large

ships. Gas from "producers" of various kinds is now very largely supplanting steam and steam boilers in works on land, and already gas engines, together with gas-producing plant, have been installed in a variety of small vessels. Some authorities anticipate that before long huge liners will be equipped with producer plant of the "suction" order, whereby gas will be generated at exactly the rate at which it will be required by the gas engines employed. While a great saving in weight, and economies in other directions, would attach to such an arrangement, it would still, of course, be necessary to carry raw fuel for the producers, but this would be relatively small in amount, much cheaper in cost, and easier dealt with than coal or other raw fuel used in steam boilers. On this and kindred subjects the address of Sir William White, already so frequently referred to, contains some weighty remarks which we here quote: "No one can fail to be attracted by the prospect of possibly dispensing with the use of steam as an intermediary, and directly using gas for internal combustion engines. Of course, in sea-going ships questions of importance arise as to the power of covering long distances, and the arrangements for generating or storing gas, as well as obtaining adequate supplies of coal or oil. We are on the threshold of this subject; and it seems probable that a great deal more must be done on land in the development and use of gas engines of very much greater power than any yet constructed before the steam boiler disappears from ships. Experiments of the character needed must not and need not be

conducted on board ships. It may be that Sir Frederick Bramwell's prediction is correct, and that in less than thirty years the use of gas engines will be almost universal. Only time can settle this question; but one thing is certain, naval architects and marine engineers will welcome and utilise any system which simplifies internal arrangements and minimises weight and space." Sir William further refers to the fact that some enthusiasts dream of a time when gas turbines instead of reciprocating engines shall be brought into use and an advance analogous to, but still greater than, that effected by the steam turbine brought about. He adds, however, that "those more competent to judge than myself appear disposed to think that very serious, if not insuperable, difficulties lie in the way of this system of utilising power." High engineering authorities are in fact agreed that the "impossible" temperature—and consequent injury to the working mechanism, no matter of what material—forms in itself an obstacle apparently insurmountable. But as to the gas reciprocating engine on board ship there is more decided and enlightened optimism. Winding up a careful discussion of the *pros* and *cons* of this subject that authoritative journal *The Engineer* says in a recent editorial: "Whilst he would be a rash prophet who would say that the days of the steam engine are numbered, there can be no question that a rival, which only a few years ago appeared insignificant, is assuming dangerous proportions."

CHAPTER V

TONNAGE-PRODUCING DISTRICTS AND COUNTRIES

WE come at last to deal, in a concluding chapter, with the volume and sources of output, rather than with the character of shipbuilding work, and the classes of shipping forming the general output. In doing this the main reasons may appear why, in both respects, Britain has so long led the world; why certain British districts have taken precedence of others in the industry; and why given districts have earned special repute in producing particular classes of ships. Brevity, however, will suffice on these heads, in view of what has necessarily had to be said with regard to them in previous chapters, but on the more important questions of to what extent Britain's long-maintained supremacy is now assailed and imperilled by competition, and by what means this supremacy may still be upheld, our remarks may be more extended.

In geographical situation, as compared with the rest of the world, the British Isles occupy the most favourable position imaginable for ready approach from abroad: for outside sustenance and succour; but equally so, of course, for predatory and malign

designs. These broad facts lie at the root of Britain's eminence in shipbuilding and shipping, and most certainly of its supremacy as a Naval Power. Approachable by nature's highway—the ocean—from north, south, east, or west: possessed of a magnificently indented coast line, with fine, natural harbours at frequent intervals, from one or the other of which no great centre of industry is much more than one hundred miles distant, it is not to be wondered at that Britain became the workshop and warehouse of the world. In this age of iron and steel, it is worth an annual sum amounting to millions to a country to be able to bring together by sea the vast quantities of raw materials—supplementing the home supplies—used in the manufacture of iron pigs and steel ingots; and in districts such as the valley of the Clyde, and the Tyne, Wear, and Tees, the natural exigencies further favour and simplify the industry of shipbuilding. Coal is brought from mines only a few miles away; iron ore and copper ore, most of which come from abroad, can be transferred without much handling—in some places indeed almost direct—to the hot-blast furnace, from the hold of the vessel which brings it from Sweden, Spain, or elsewhere. From the smelting works to the shipyard is but a short step, and in this way the cost of bringing together the raw material necessary for construction—one of the most serious items in modern shipbuilding—is reduced to a minimum.

In the early days of British shipbuilding, when the stately three-deckers and other of England's "wooden walls" were so important a factor in the nation's life

and development, it was a matter of even more vital importance for a shipyard to be near a timber forest than it now is—when "iron sides" have long usurped the proud position of "wooden walls"—for a shipbuilding centre to be in the proximity of coal mines and iron and steel works. Hence, for example, the neighbourhood of the Solent—in the proximity of the New Forest and surrounded by excellent natural harbours—was in those early days a great centre of the shipbuilding industry. Perhaps had the cheap locomotion now prevailing been then possible, wood shipbuilding might have retained its position longer in certain districts, and might also have spread to others more than it did. Even three-fourths of a century ago the practice and industry of shipbuilding were widely distributed along our splendidly indented coast line, backed by natural supplies. But the home supply of oak and other timber suitable for shipbuilding grew gradually scarce and expensive. The imported materials becoming more and more so, the introduction of metallic shipbuilding had the way prepared for it—craftsmen's prejudices and conservatism, backed by popular unbelief, notwithstanding. The country, in fact, had attained to the fit state of preparedness for utilising properly its mineral resources.

Shipbuilding in wood, however, lingered in the Royal Dockyards even in the face of such influences, until absolutely forced to abdicate by the overwhelming tide of favour for shipbuilding in metal. Tradition, convention, prejudice are indeed dragons to deal with, and in this connection it is amusing to

read in a recent and "up-to-date" American journal, a lamentation over the decay and desuetude of wood shipbuilding in some of the States there, and a recapitulation of some of the old-time arguments for wood vessels in preference to iron ones. Referring to Great Britain, the journal in question remarks: "It is safe to say that the iron and steel shipbuilding industry was developed there primarily because the native materials were available, and could be cheaply manufactured, whereas the materials for the construction of wooden vessels had become scarce and expensive. When the British flooded the seas with their iron vessels only the domestic commerce was left to American builders of wooden ships." Under the protective policy so long pursued by America, shipbuilders there have been secured from the encroaches of foreign competition. They have built vessels for their own "domestic commerce," enjoyed their own pace, but at a tremendous sacrifice. Preferring to take the material most at hand, the manipulation of which they well understand—notwithstanding that the other modern "native materials" referred to are as readily available there (in greater magnitude too) as in the old country—they have allowed their wood age to be dovetailed half a century into our iron one, and have in consequence been long in obtaining that share in the world's work, both as regards shipbuilding and shipowning, which the greatness of the New World is entitled to. Since 1884–5, however, when the naval authorities of America started out on the rehabilitation or creation of their ironclad navy, and produced the trinity of cruisers—the *Chicago*, *Boston*,

and *Atalanta*—all built of mild steel of American manufacture, but moulded, as regards many of their general arrangements, on the practice of this country, America has taken a larger and more important share in shipbuilding, even for other than "domestic" requirements.

The importance of shipbuilding, in a purely industrial sense, is especially far-reaching, and in Britain though there may not be more than from 200,000 to 300,000 artisans in the shipbuilding establishments, quite a million workers—not however in Britain solely—are directly and indirectly dependent on the construction of ships. The mining of the ore at home and abroad; the smelting in the blast furnace; the refining in the open-hearth or basic furnace; the rolling of plates and bars; the forging and casting of structural items; the transport of metal and minerals—all these involve tremendous capital and afford employment to vast numbers of workers; while, if it is also considered that the various subsidiary branches of industry, such as pump-making, tube-making, winch- and windlass-making, anchor- and chain-making; and the making generally of the multifarious auxiliaries and accessories involved in a modern ship's structure and outfit, are the necessary complement of the shipyards and engine shops, the stupendousness of the capital and labour involved may be imagined. The result is seen in the completion each year of vessels whose tonnage aggregates from 1,300,000 to 1,800,000 gross register tons, and whose monetary value has been appraised at from thirty-five to forty millions

sterling. All other countries put together produce considerably less than these amounts, and with the exception of the United States (and sometimes Germany) no other single country produces a yearly tonnage equal to the output of the Clyde alone.

The change from wood to iron in construction, and from sail to steam in propulsion, having had the effect of concentrating and localising the shipbuilding industry in those districts which, besides possessing the *sine qua non* of ready outlet to the ocean, are favoured in being the repositories, or within ready access, of vast stores of coal and ore, it was but natural that the Clyde should become an important shipbuilding centre. Nature has been specially bountiful to the valley of the Clyde in the latter of these respects, and what Nature has denied in the other case, the persistence and skill of Clydeside men have wrested from her. The Clyde, in fact, as a waterway, is one of the least endowed by Nature to be the mother of great ships, and for the larger part it is even now comparatively shallow and somewhat tortuous. But commercial and industrial astuteness, supplemented by engineering skill and prescience, have nobly made up for natural limitations. It has been by sheer, persistent, and constantly increased dredging, that this water-way (or canal, as it might reasonably enough be called) has been maintained and improved. It is not by accident, therefore, that the Clyde has all along been the birthplace of specialities and craft concerned with river, harbour, and dock improvements.

Coequal at least, and on the whole concurrently,

with the improvement of the river—although shipbuilders themselves are prone to maintain that enterprise in this matter waits too long on experience—industrial development and progress have proceeded regularly, and on the whole constantly, from the time when the Clyde became identified so intimately with steam engineering and iron shipbuilding. The productive powers of the establishments lining its banks have always been maintained at something more than the highest demands. If shipbuilders and engineers have always been abreast, often in advance, of general progress in the science as well as the art of their calling, Clyde men have been associated, as may have been gathered from what has gone before, with practically every scientific advance in naval architecture for the last century. Through all the transitions—wood to iron, iron to steel, paddle to single-screw, single-screw to twin-screw, twin-screw to multiple-screw turbine engines—Clyde shipbuilders have been to the front with exemplar ships. The advantages of triple-expansion engines were first demonstrated in 1874–82 in Clyde-built vessels, and now (1904–5) the practicability and immense possibilities of the most radical of all departures since marine steam engineering began have been demonstrated and put on an established plane of advancement in vessels also built and chiefly owned there.

In productive capacity, purely, it is not of course contended that the Clyde alone of all shipbuilding centres has shown enterprise and advance commensurate with the growth of the world's shipping trade. The north-east coast of England districts—the Tyne,

the Wear, the Tees — are all remarkable enough cases in disproof of this, while in the case of Belfast an example is afforded quite unique as regards many features of work achieved against natural disadvantages. But great variety of work, and for all sources of custom, has long distinguished the industry of the Clyde more than that of all other districts. The significance underlying the long-familiar term "Clyde-built" was not meaningless, nor was it easily come by! It conjured orders of all kinds from all quarters of the world, some of which doubtless, as time wore on, and especially with the spread of skill and the equalising influences of the shipping registries, etc., might safely enough have been entrusted to builders in other centres. The Mersey, as has been seen, was from the very start of iron shipbuilding a centre of consequence, and at least in part the prestige has remained, the firm of Lairds—now Lairds, Cammell, and Company—being second to none in quality of work accomplished. Belfast and Barrow, for many years, and now the Tyne and other centres, share in the very highest class of work, while in respect of naval work, the Tyne, Barrow, and other centres divide the honours at least equally with the Clyde.

Generally speaking, the number of separate yards on the Clyde for many years, without counting a number of the very smallest yards—little more than launch and boat-building premises—has been from thirty-five to forty. Many of the largest of these, such as that at Fairfield, at Clydebank, Beardmore's at Dalmuir, Denny's at Dumbarton, and Scott's and

Caird's at Greenock, have engine works connected or closely adjoining, but the larger number are dependent for the engines of their vessels on separate engineering establishments. In busy times, the largest of the combined establishments, such as Fairfield and Clydebank, employ each from 6,000 to 8,000 workmen, the larger portion being skilled artisans. Altogether the shipbuilding and engineering works, including the subsidiary branches spoken of, afford employment to between 100,000 and 150,000 workmen, varying of course with the general condition of trade. As a measure of the productive capacity of some of the busiest shipyards, it may be stated that for the past thirteen years the output of Messrs. Russell and Co., Port Glasgow, has averaged 18·8 vessels, aggregating 50,000 tons per annum; and during the past thirty years they have added to the world's mercantile marine the huge total of 1,117,150 tons gross register. It should perhaps be added that for many years Messrs. Russell and Co. built sailing tonnage very largely, and that all the engines for their steamers have been made by independent engineering firms.

The Tyne, as has been seen, began shipbuilding in iron in 1842, and as showing the great local development that soon took place in the industry, it may be noted that during the five years 1850–4 there were built on the Tyne 128 vessels of 34,121 tons, averaging 266 tons; whereas during the year 1895 alone there were built 112 vessels of 174,047 tons, with an average of 1,554 tons. The Wear, Tees, and Humber were not long behind the Tyne in commencing the construction of iron vessels, and the importance of

the industry at the north-east coast centres of the present day can be judged of from the fact that whereas in 1886 the combined output of the Tyne, Wear, Tees, and Hartlepool, with on the average fifteen, twelve, and ten shipyards respectively—thirty-seven in all—and a considerable number of separate engineering works, was practically the same as that of the Clyde district by itself, three years later the combined output of the three rivers was just double that of the Clyde. By 1901, the first year of the new century, the three northern rivers—usually considered as one by the shipbuilders of these districts in comparing output with the Clyde—may be said to have each had a sufficiently good standing of its own to bear comparison with the Scottish river. In that year the output of the Tyne was, roughly, 306,000 tons; of the Wear, 267,000 tons; and of the Tees and Hartlepool, 315,000 tons; all as against the Clyde's 513,000 tons. This relative position has, broadly speaking, been since maintained, while, as has been stated, variety and high quality are features which have increasingly marked the work of all the centres. Enough, however, has now been said of these local aspects of the subject of volume of output, and some general statistics may be given on the subject of output as concerned with the aggregate production in the yards of the United Kingdom, and in those of countries now recognised as competing with Great Britain in producing ships for both home and foreign ownership.

So recently as 1890 British shipbuilders supplied the great bulk of shipping required by foreign owners.

In 1895 they built to foreign account 190,000 tons; but during the last three years of the century the average proportion was about 250,000 tons, thus showing that even then in a general way the shipbuilders of other countries were not able to cope with the demands of their own shipowners. For all essential purposes, therefore, of showing the present-day position of the shipbuilding industry in Britain, and in the principal foreign shipbuilding countries, it is not necessary that figures should be given for more than the past half-dozen years. The position, from various points of view, as concerns the United Kingdom, during the period named, is well indicated in the subjoined table, for which for arrangement, and largely for data, we have to express indebtedness to the courtesy of the editors of *Engineering*.

In this table it will be seen that there is no accurate differentiation between merchant shipbuilding and shipbuilding for purposes of war, except that the warship building carried out in the Royal Dockyards is stated. An outstanding fact exhibited by the table is that the year 1901 forms the high-water mark in the productiveness of British shipyards, the grand total for that year being, roughly, 1,811,000 tons. For the two years following there is a growing decrease; in 1902 of 168,450 tons, and in 1903 of 406,920 tons, a sensible recovery being exhibited in the 1,421,600 tons for 1904. Other interesting features brought out in the table are: the proportion of sailing tonnage produced, the percentage of steam to the total output of merchant ships, the percentage of all naval tonnage to merchant ship tonnage, the

TABLE I.

Aggregates of Production in the United Kingdom.

	1904.	1903.	1902.	1901.	1900.	1899.	1898.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Steamers*	1,316,100	1,328,987	1,501,806	1,683,723	1,622,062	1,638,074	1,565,305
Sailing ships	48,400	46,742	89,127	62,313	34,558	36,583	34,957
Totals	1,364,500	1,375,729	1,590,933	1,746,036	1,656,620	1,674,657	1,600,262
His Majesty's Dockyards	57,100	28,290	51,560	64,910	5,230	66,900	70,955
Grand totals	1,421,600	1,404,019	1,642,493	1,810,946	1,661,850	1,741,557	1,671,217
Foreign-owned tonnage	247,700	221,292	283,002	364,379	430,495	356,483	391,504
Per cent. of total	17·4	15·7	17·3	20·8	26·0	20·1	24·4
Total merchant tonnage†	1,294,200	1,251,036	1,549,449	1,599,404	1,600,421	1,576,465	1,477,864
Per cent. of steam merchant tonnage to total merchant tonnage	96	96·2	94·4	96·1	97·8	97·7	97·57
Indicated horse-power of engines	1,359,200	1,364,778	1,314,502	1,502,203	1,263,079	1,540,814	1,432,829
Per cent. of all naval tonnage to merchant ships built	9·85	12·2	6·24	13·2	3·84	10·6	13·7

* Includes warships built in private yards.

† Excludes British and foreign warships.

TABLE II.

Countries where British-built foreign-owned ships were registered.

	1904.	1903.	1902.	1901.	1900.	1899.	1898.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Norway and Sweden	62,105	30,464	24,285	11,291	17,861	22,604	64,452
Colonies and India	44,551	28,840	76,326	26,239	5,984	14,999	21,286
Germany	25,899	28,590	35,891	78,157	110,722	70,648	50,297
Holland	2,379	23,755	19,742	43,184	28,931	17,617	21,590
Austria-Hungary	32,953	18,480	39,267	53,970	82,127	13,328	6,735
France	12,540	15,535	8,074	18,777	28,436	4,285	4,612
Russia	12,356	12,981	11,767	31,736	16,985	8,440	23,327
Greece	15,035	11,902	21,272	8,597	3,295	—	3,430
United States	1,226	11,488	3,380	132	5,104	3,450	4,161
Denmark	12,098	7,801	3,103	12,279	6,151	18,393	39,527
Spain	3,555	7,092	7,533	9,505	20,236	25,584	4,224
Turkey	—	6,830	—	—	—	—	—
Belgium	2,713	5,065	240	199	—	—	9,828
South American Republics	7,278	3,079	288	1,670	8,078	6,036	6,107
Portugal	44	1,554	—	—	—	—	—
Japan	—	132	2,000	8,505	35,000	45,880	60,711
Italy	—	—	3,890	2,875	—	—	—
China	80	—	3,262	1,400	4,140	300	20,624
Other countries and unclassified	11,945	7,604	22,682	52,478	—	—	—

indicated horse-power of the engines produced, corresponding to the steam shipping. The later figure, however, includes some engines for steamships built abroad, as well as some for other than propulsive power purposes. Another feature brought out, and from the present point of view the most important feature, is the percentage of foreign-owned tonnage to the total output. Of this more will be said presently. Tables might also be given designed to exhibit the growth of steel as compared with iron shipbuilding, as well as the growth in ship dimensions, capacity, power, and speed, but on all these heads sufficient perhaps has been said in previous chapters.

There is, as will be seen from the table, since the year 1900 a continued and considerable decrease in the amount of tonnage built for foreign owners. Last year's proportion of work of this description relatively to the total was 17·4 per cent., as compared with 15·7 per cent. in 1903, 17·3 per cent. in 1902, 20·89 per cent. in 1901, and 26·0 per cent. in 1900. The proportion in 1897 was as high as 27·69 per cent., while in 1896 it was 30 per cent., and in some previous years 32½ per cent. In the north-east coast districts there has also been a continued decrease in foreign-owned tonnage, but less marked than in the case of the Clyde. On the Tyne, the diminution is illustrated by the proportion for 1903 having been 23·3 per cent., as compared with an average of 35 per cent. in the nineties.

Table II. sets forth the principal foreign shipowning countries, and the tonnage which each has been supplied with by British builders during the years 1898–1904 inclusive.

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Countries where British-built foreign-owned ships were registered.

	1904.	1903.	1902.	1901.	1900.	1899.	1898.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
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Colonies and India	44,551	28,840	76,326	26,239	5,984	14,999	21,286
Germany	25,899	28,590	35,891	78,157	110,722	70,648	50,297
Holland	2,379	23,755	19,742	43,184	28,931	17,617	21,590
Austria-Hungary	32,953	18,480	39,267	53,970	82,127	13,328	6,735
France	12,540	15,535	8,074	18,777	28,436	4,285	4,612
Russia	12,356	12,981	11,767	31,736	16,985	8,440	23,327
Greece	15,035	11,902	21,272	8,597	3,295	—	3,430
United States	1,226	11,488	3,380	132	5,104	3,450	4,161
Denmark	12,098	7,801	3,103	12,279	6,151	18,393	39,527
Spain	3,555	7,092	7,533	9,505	20,236	25,584	4,224
Turkey	—	6,830	—	—	—	—	—
Belgium	2,713	5,065	240	199	—	—	9,828
South American Republics	7,278	3,079	288	1,670	8,078	6,036	6,107
Portugal	44	1,554	—	—	—	—	—
Japan	—	132	2,000	8,505	35,000	45,880	60,711
Italy	—	—	3,890	2,875	—	—	—
China	80	—	3,262	1,400	4,140	300	20,624
Other countries and unclassified	11,945	7,604	22,682	52,478	—	—	—

From the above it will be seen that Norway and Sweden, Holland, Russia, and Austria-Hungary, have, generally speaking, proved steady customers; but in the cases of Germany and of Japan the table suggests—especially regarded alongside the figures given on Table III. following—the extent to which shipowning has advanced in these countries, and the extent to which they are now supplying their own requirements. In this connection it would appear that Japan, the Island Kingdom of the Far East, has for the time being become quite self-supporting, while as regards Germany the 25,890 tons supplied by British builders last year is much less than a fourth of the amount supplied in 1900, since when there has been a steady decrease. France, which took from us 12,540 tons last year, and 15,535 tons the year previously, doubled her custom as compared with the year 1902, but fell away very considerably from the figures for 1900, which were 28,436 tons, and 1901, 18,777 tons. France, of course, as is well known, has for a number of years past, owing to the Bounty System, been building most of her own vessels, especially of the sailing class, although depression has also overtaken this industry. The United States, it is of interest to note, are credited with having taken from us, in 1903, 11,488 tons, more than double the tonnage for any previous year since 1898. The figures almost entirely refer to steam yachts, which do not come under the injurious Navigation Laws imposed on American owners of merchant ships. America's continued custom, it may be marked, although

limited, is a tribute to the superior design and the magnificent finish of these palatial pleasure craft, which are chiefly of Clyde build.

Whether British shipbuilders will in any future year exceed or even attain to the record of 1901 is a question very seriously debated by those who take a broad view of the shipbuilding progress and facilities of other countries as well as of Britain. There is, of course, a natural "cycle" or periodicity in shipbuilding activity, due to trade exigencies which affect Britain quite as much as other countries, and this together with the general fact of the constantly increasing size of ocean vessels (especially of the combined cargo and passenger type) discounting and displacing the more numerous moderate-sized vessels of the tramp order, and of the sailing class, are all considerations which help to account for the shrinkage in British output which has marked the past three years. The principal explanation of the shrinkage, however, is the extent to which foreign countries —formerly our customers entirely—are now either building for their own needs or satisfying their requirements from other shipbuilding countries than our own. In the building of warships also Britain is now feeling the effect of foreign competition. It is a natural desire of foreign nations that such vessels as are required for their national navy should, if possible at all, be of home construction. This patriotic ambition has not only had its effect in diminishing the number of orders entrusted to Britain for warships, but has done much to develop the building of merchant ships in countries where shipbuilding was not

previously carried on to any great extent, as well as to spread the area from which new ships are ordered. These remarks apply in the cases of Italy, Austria, China, Japan, and, in a limited sense, of Russia, Germany, and the South American Republics. It is at least undoubted that in European countries and in the United States much more work is now being done for foreign navies than was formerly the case.

Before giving figures as to the volume of shipping (both naval and mercantile) produced abroad in recent years, it may be instructive here, in view of what will afterwards be said as to Britain's present position, to reflect a little on how foreign countries were helped originally by ourselves to become our competitors. Prior to, say, 1890, Britain still held the field as world's shipbuilder, but since that time foreign demand on British resources and skill has diminished, and the basis of success in shipbuilding has been laid in other countries. For much of this foreign success Britain undoubtedly paved the way. The early typical ships for foreign lines—for example, those of Germany, France, Russia, and Japan—were built in this country, and with the finished vessels there were provided (for a consideration of course) complete sets of drawings and models, so that it became a simple matter for the foreign shipowner to supply the foreign shipbuilder with the necessary information and guidance from which to build sister ships. Very often, too, when builders in this country secured contracts for new vessels to foreign account, it was a stipulation that the sons or young relations of the foreign shipowner should be

FITTING-OUT CRANE OF "DERRICK" TYPE AT MESSRS. BLOHM AND VOSS'S ENGINEERING WORKS, HAMBURG

taken into the yard or shops of the contracting builders, and given an insight into a systematic coaching in the various branches of ship design and construction. With the completed ships, therefore, there passed directly to the foreign shipowner and builder trained and more or less competent advisers. Our colleges and universities, too, have afforded to young foreigners means of scientific education, and this has been a factor of considerable moment in the progress made with at least naval shipbuilding abroad, especially in America and in Japan.

The volume of shipping, both naval and mercantile, produced in foreign countries and our colonies during the past four years is summarised in Table III. (page 186), which is from a very interesting return issued by Lloyd's Register early in 1905, reviewing the work done last year in the United Kingdom and the output of foreign countries. While the table includes naval as well as mercantile tonnage, it should be noted that—as is the case in all Lloyd's returns—the figures do not take cognisance of vessels of any kind whose tonnage is less than 100 tons. This accounts for the disparity in the totals as compared with the figures in our other tables; but it does not, for comparative purposes, as between country and country and from year to year, detract from the interest and value of the statement.

That the United States and Germany are our most formidable competitors will be readily enough gathered from the table. Their respective outputs are by far the largest, and they show a constant tendency to creep up towards the British figures. In the twenty

TABLE III.

Tonnage of Ships Launched (including Warships) in each Maritime Country.

	1904.	1903.	1902.	1901.
Austria-Hungary	28,125	28,848	23,361	27,413
Belgium	6,686	12,804	14,946	5,631
China	709	2,364	3,400	3,694
Denmark	15,859	32,059	27,148	26,056
France	124,845	123,528	236,635	232,404
Germany	247,167	245,084	257,885	284,063
Holland	61,404	59,594	73,973	35,856
Italy	58,678	57,389	62,288	88,329
Japan	33,577	41,004	36,481	37,208
Norway	50,469	41,599	37,878	36,875
Russia	8,143	45,404	52,579	39,890
Sweden	10,375	15,505	9,030	19,191
Other European countries	3,436	3,669	5,507	2,496
United States	409,403	450,090	396,433	481,138
Other countries	763	592	—	—
Colonies	30,965	34,690	28,819	28,134
Total foreign and colonial	1,090,604	1,194,223	1,266,363	1,348,378
United Kingdom	1,332,337	1,342,508	1,521,698	1,736,708
Total for world	2,422,941	2,536,731	2,788,061	3,085,086

years prior to 1901 the number of shipyards in Germany increased from 18 to roughly 18 to 35, and the employees increased fivefold, from about 8,000 to nearly 40,000. In America there has been an even more striking development in a later and shorter period. Entirely new shipyards or greatly extended existing ones have there grown up with mushroom-like rapidity, plentifully equipped with plant of the most modern description and capacity. Probably the best indication of this, and of the advance in the apparent capability to construct large and high-speed modern ships, is embodied in the fact that whereas only a few years prior to 1901 three or four firms at most were found entering into competition for the construction of battleships and large cruisers, the official invitation for tenders for battleships in the year named brought in bids from ten separate firms. However, on the subject of American shipbuilding there is much to say of a less decided character than might seem to be conveyed in these statements. The United States and their statesmen and captains of industry have been long divided on a variety of large questions vitally affecting shipbuilding and navigation, and conflicting interests have long debarred that sort of legislation which to outsiders at least readily enough appears necessary to reform and progress. The whole subject is a very complex one, and the reasons why, in spite of such expansion in the facilities for shipbuilding, there has been nothing like corresponding expansion in American shipping are, of course, difficult to assign. It may still be, to some extent, as it doubtless long was, attributable to the

immense opportunities which the United States offer for the employment of capital and skill in other directions. Their shipping and shipbuilding activity has undoubtedly a huge field in the great coasting trade of the Pacific and Atlantic and on the Great Lakes. But the greater cost of shipbuilding, due partly to the higher wages, but more especially to the higher cost of materials caused by protective tariffs, undoubtedly accounts for the lack of expansion in shipping in other than the fields named. Since early in the nineties enterprise has certainly not been a-wanting, but reform and development would seem to have been sought after from the wrong end. The fact that America, during the war with Spain, had to buy some fifty foreign vessels for transport purposes rankled, it is asserted, in the bosom of the shipping fraternity, in spite of the fact that in this way she got ships more cheaply than if she had built them herself. However this may be, it is at least certain that shipping on the scale attempted within recent years is a fluctuating and expensive industry, as may be judged alone from the number of bankruptcies that have had to be announced.

Mr. Cramp, of the famous Philadelphia Shipbuilding Company, maintained not long ago that it now costs a good deal more than 25 per cent. above the British level to build steamers in America. Some material, he says, costs 60 per cent. more in the States than in Britain. This may be so, though why plate and angle steel should not be obtained as cheap or considerably cheaper in America than what such material costs our shipbuilders is perhaps not an

impertinent question. In regard to shipping for the Navy, considerations of official indecision and extravagance, not to say ineptitude, are given as accounting for high cost and slow production; but these considerations do not in the same way affect merchant shipping. American shipowners say that they can make money by buying foreign ships and sailing them under foreign flags. Why should they not be allowed to buy foreign ships and sail them under the American flag? The reason seems to be that the shipbuilding and the various protected industries do not wish this to be brought about. Until American shipowners are permitted to buy their wares in the cheapest market, and American shipbuilders and steelmakers are truly put on their mettle to reduce cost and secure possible, but at present non-existent, economies in their work, they will never be brought into legitimate competition with their foreign compeers, and an adequate American merchant navy, taking its due share in the general carrying of the world, will still be in the distance. America must realise as a whole that it would be easier and less expensive for the nation to do all in its power to make it possible to have ships of low cost than to seek to make high cost and expensively operated ships profitable in the international competition. In the case of Germany there has been some departure from its general protective policy, which has been forced upon it, and materials for shipbuilding have been to a considerable extent admitted free to German shipyards. These facts, together with subsidies and other advantages given by their Govern-

ment to German shipowners, have led to expansion in German trade generally, and of course to expansion in shipping and shipbuilding.

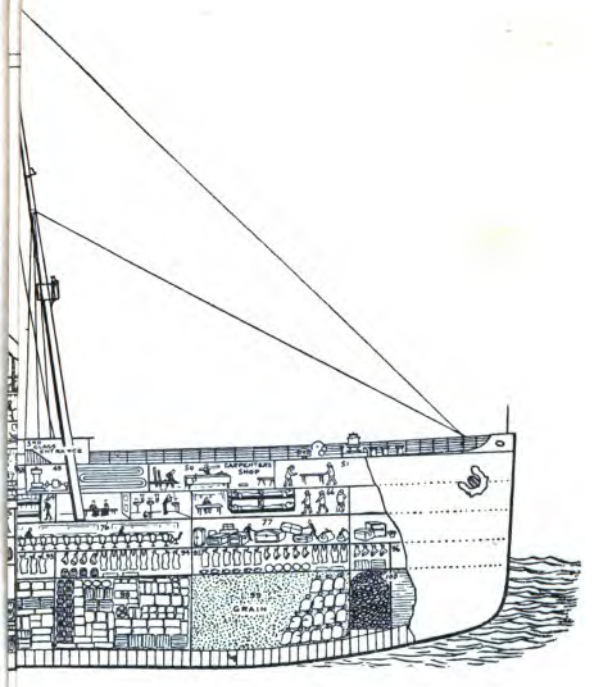
From what has been previously said as to Britain supplying designs and exemplar ships, it is not to be inferred that the foreign shipbuilder and naval designer have been merely copyists of British methods. In many respects, indeed, British practice has been improved upon; and in such matters as the strength of ships, average speed maintained at sea, the absence of vibration at high speed, as well as the increased capacity and general economy of ships, there is now much which British shipbuilders must not disdain to learn from their foreign competitors. This is especially true in matters with which the employed, as well as the employers, are concerned, viz. the working methods and the time worked. The greater steadiness and tractability of workers in Germany and in America form one important reason for the progress made in recent times. There is not the same time lost or wilfully squandered, nor are the same objections raised by the workers in either of these countries to the introduction of new and labour-saving tools. Generally speaking, there is in America, and also in Germany, much less effort put forth either to limit the amount of work a man may do or to fix uniform and arbitrary rates of pay. Individual skill and industry have full play—and fairer play—and with a new machine or with improved methods a workman seeks to make the most of his opportunities. Fair remuneration in this way is easily arranged for, and broadly speaking, this has been based on the rule of half the increased production due to the new tool

or improvement being credited to the operator's wage, the other half going to the employer in return for the extra capital involved in providing the improvement.

The efforts made by the workers in this country to limit the speed at which a tool may be worked and to limit one man's attention to one tool have, since the great engineering struggle on these questions, in 1897, been inoperative or at least ineffectual; but as compared with what obtains in America, there is still backwardness here in this respect, and workers must still more keenly realise the effect of such a state of matters on the competition now being met with from foreign countries. The use of compressed air and electric tools for riveting, drilling, and caulking is a subject already fully dealt with, and it may be sufficient here to say generally that it has been more owing to labour prejudices and restrictions than to any deficiencies of these tools for the work to be done that they have so far found greatly less adoption in this country than in America and on the Continent. British shipbuilders—workers as well as employers—have in this matter, as well as in the electric crane equipment over their berths, also already fully referred to, examples of the further possible economies in cost of production. Their ready acceptance and full utilisation by our foreign competitors are matters which are jeopardising Britain's long-standing position as the greatest shipbuilding country in the world.

Questions of fiscal policy are at present agitating trade and industrial circles in Britain and her Colonies, and without doubt the settlement of Mr. Chamberlain's

proposals, one way or another, has a very vital bearing on the continued eminence of British shipbuilding and shipping. Should an import duty be imposed on shipbuilding material from America or the Continent, home manufacturers might welcome the change as securing them in the home market "full prices"; but as vendors and users of cheap ships, shipbuilders and shipowners are naturally averse to too indiscriminately imposing a tax on cheap and good material from abroad. If foreign makers can supply suitable material at less cost to the consumer than our own, it is not only to builders' interest, but for the shipowners'—and largely therefore the nation's—benefit that the foreign material be used. This is the case in all its baldness for British shipbuilding and shipping. No doubt it is hard on the home manufacturers, but they are not the men to sit down under temporary discomfiture. New conditions and new forces will stimulate other methods and new economies. Meantime, as things exist, we may generally endorse a recent writer, to whom shipbuilding in several countries is an open book, when he says: "Britain has no need of bounties for shipbuilding. As all the materials exist in the country, builders have not to pay transport expenses and heavy import duties such as handicap their competitors. She has a good start and a grand reputation. Let her not trade too much on either, but put more system into the management of the yards, introduce automatic tools and the metric system, keep up the standard of the work turned out, and she has nothing to fear from foreign competition on either side of the Atlantic."



I

CLASS DINING ROOM
GE ROOM
ATE STEERING GEAR BELOW
OOM [WATERLINE

IC ENGINES
T OF MAIN ENGINES

ROOM

ROOM

ROOM

91 STORES ROOM
92 DO.
93 COLD STORAGE ROOM
94 DO.
95 DO.
96 DO.
97 CARGO
98 DO.
99 DO.
100 CHAIN LOCKER
101 SHAFT TUNNEL
102 DOUBLE BOTTOM
103 TUNNEL
104 DO.
105 DO.

INDEX

Aaron Manby, first iron steamer, 31
Accommodation, first Canadian steamer, 26
Admiralty and adoption of mild steel, 68, 69
— and subdivided ships, 55
Adriatic, Collins liner, 14
Æolipile, Hero's, 139
Aglaia, first Clyde-built iron steamer, 32
Alaska and *Arizona*, Guion liners, 62
Albion, turbine steam yacht, 150
Alfred the Great, ships of, 8
Allan Line, founding of, 46
— liners, 70, 76, 149, 151
American shipbuilding, 171, 185, 187
— — high cost of, 188
— shipping laws, 182, 189
Amethyst, turbine cruiser, 148
Anchor Line, founding of, 46
Ancient canoes, etc., 1, 2
Archimedes, early screw steamer, 45
Ark, Noah's, 2, 3
Armstrong, Whitworth, and Co., 142, 150
Artisans, number employed in shipbuilding, 172
Atlantic fast passages, 66

Balanced reciprocating engines, 140
Ballast, water, in ships, 53
Baltic, White Star liner, 74
— launching weight of, 113
Barrow-in-Furness, shipbuilding at, 134, 175
Beardmore, William, and Co., and berth equipment, 105
Belfast as a shipbuilding centre, 173
— and big steamers, 74
Bell, Henry, and early steamboats, 21
Bending blocks, work on the, 90
Biles, Prof. J. H., 119
Biles, Gray, and Co., and Channel steamers, 145
Board of Trade requirements, 56
Boiler pressures, 78
Boilers, water-tube, 78
Bounty system in shipbuilding, 182, 192
Breaking-up of old ships, 57
Brighton, turbine Channel steamer, 145
Britain as a tonnage-producing country, 168, 179
Britannia, early Clyde steamer, 24
— pioneer Cunard liner, 44
Britannic and *Germanic*, White Star liners, 62
British Corporation Register of Shipping, 40
— aid to foreign shipbuilders, 184
— India Steam Navigation Co., 150
Brock, Walter, and quadruple expansion engines, 78
Brown and Co., John, and Cunard liners, 75, 156
Brunel, I. K., 27, 33, 34, 50

Buenos Ayrean, first steel Atlantic liner, 70
Building-berth crane equipment, 103, 191
Bulkheads, watertight, subdivision by, 54, 94
— doors, 57, 59
Bureau Veritas, register of shipping, 39
Butts and their fastenings, 97

Campania and *Lucania*, Cunard liners, 65
Canadian pioneer steamers, 26
Canoes, etc., ancient, 1, 2
Car of Commerce, early Canadian steamer, 26
Cargo, rapid loading and unloading of, 130
Carmania, turbine engines of, 159
Caronia and *Carmania*, Cunard liners, 75, 159
— launching weight of, 113
Carthaginian trading ships and war galleys, 5
Caulking of plate edges, 112
Cellular construction of ships, 36, 51
Celtic and *Cedric*, White Star liners, 74
Charlotte Dundas, first practically successful steamer, 20
China, first Cunard screw steamer, 47
China tea clippers, 43
Chinese as navigators, 5
City of Glasgow, first Inman liner, 47
City of New York, Inman liner, 63
City of Paris, Inman liner, 63
City of Rome, Inman liner, 62
Clermont, Robert Fulton's, 22
Clyde, the, as a shipbuilding centre, 171, 175
— number of shipyards on, 175
Clyde and *Elizabeth*, early steamers, 23
Coal consumption at high speeds, 148, 153
Cobra and *Viper*, turbine torpedo-boat destroyers, 142
Collins Line, 14, 46
Collision bulkhead, 56
Columbia, Hamburg-American liner, 64
Columbus, ships of, 8
Comet, Henry Bell's steamboat, 21, 23
Commercial qualities of ship types, 124, 127
Composite-built ships, 42
Compound surface-condensing engines, 76, 77
Compressed air tools, 103, 112, 185
Coppering of wood ships' hulls, 41
Coracles, 2
Corrosion and fouling of iron and steel ships, 41
Cox and King, yacht designers, 147
Cramp, Mr., on shipbuilding costs, 188
Crane equipment over building berths, 102, 103, 185
Cranes, powerful fitting-out, 117
Cretans as navigators, 5
Cunard liners, 44, 62, 63, 75, 159

Dalswinton Lake steamboat experiments, 19
Deane, Sir Anthony, 12
Denny, William, Dumbarton, 24, 25
Denny, William, and Brothers, and steel shipbuilding, 70
— — and model experiments, 85, 86
— — and progressive speed trials, 119
— — and double-bottom ships, 53
Design, work of, in drawing office, 82, 87
Deutschland, Hamburg-American liner, 66
Dockyards, Royal, 12, 13
Double-bottom ships, introduction of, 52
Doxford, William, and Sons, and berth equipment, 105
— — and shell-plate joggling, 98

Doxford, William, and Sons, and "turret" steamers, 127
Draught plan, description of, 88
Drawing office operations, 81, 88
Dredgers, steam, 132
"Dug-outs," 1
Duncan, Robert, builder of first Cunard steamer, 44
Dundas, *Charlotte*, first practically successful steamer, 20

Economies in ship construction, 125, 191
Eden, turbine torpedo-boat destroyer, 148
Educational agencies in naval architecture, 119
Elburkah, early iron steamer, 33
Elder, John, and compound engines, 76
Elder, Mrs. John, and naval architecture, 119
Electric cranes over building berths, 105
Electric propulsion, 164
Elgar, Dr. Francis, 119
Emerald, turbine steam yacht, 147
Ericsson, John, and screw propulsion, 45
Experimental tanks, 84, 85

Fairbairn, Sir William, and iron shipbuilding, 29, 34, 35
Fairfield-built Atlantic liners, 62, 63, 74
Fairing lines in mould loft, 89
Fairy Queen, first iron steamer on Clyde, 32
Ferguson Brothers, and steam dredgers, 132
Fiscal policy as affecting shipbuilding, 191
Fitch, John, and early steamboats, 17, 18
Flanging of plate edges, 101
Fleming and Ferguson and steam dredgers, 132
Foreign-owned ships built in Britain, 181
Foreign shipbuilders aided by Britain, 184
Forth and Clyde Canal, first steamer on, 20, 21
Fouling and corrosion of iron and steel ships, 41
Frame-bending, work of, 91, 123
Framing of modern ships, 92, 123
France and submarine boats, 134
Francis B. Ogden, early screw steamer, 45
Freeboard and seaworthiness, 56
Froude, Dr. William, and model experiments, 84, 85
French shipbuilding, 182
Fuel consumption in boilers, 79
Fuel, liquid, 160
Fulton, Robert, and early steamers, 17, 21, 26
Furness, Withy, and Co., and long shell plates, 101, 121
Fürst Bismarck, Hamburg-American liner, 64

Galleys, ancient, and slave labour, 15
— war, of Greece and Rome, 5, 15
Garryowen, early iron steamer, 33
Gas-producers on board ship, 166
Gas marine engines, 165, 167
Germanic and *Britannic*, White Star liners, 62
German Atlantic liners, 66, 67
— shipbuilding, 181, 185
Gopher wood in Noah's Ark, 3
Grangesburg, turret steamer, 130
Great Britain, pioneer iron ocean steamer, 28, 34, 36, 45
— *Eastern*, 36, 49
— *Michael*, 9
— *Western*, pioneer Atlantic liner, 27, 28, 36
Greeks, ships of the, 3, 4, 5
Guion liners *Alaska* and *Arizona*, 62

Hall, Samuel, and surface condensers, 77
Hamburg-American liners, 64, 75

Harland and Wolff and leviathan steamers, 75
Hartlepool, as a shipbuilding centre, 177
Hawthorn, Leslie, and Co., Newcastle, 147, 148
Henry Grace à Dieu, or *Great Harry*, 9
Henry, William, and experimental steamboats, 16
Holland type of submarine boats, 134
Holt, Alfred, and structural devices in ships, 126
Howden's system of forced draught, 163
Hulls, Jonathan, steamboat proposals of, 16
Hydraulic power riveting, 103, 106, 107

Industry, early Clyde steamer, 24
Inglis, A. and J., and double-bottom ships, 53
Inglis, Dr. John, and shipbuilding science, 119
Inman Line, founding of, 47
— liners, 62, 63
Insurance Societies and steel ships, 73
"Intermediate" class of ocean liners, 80
Internal combustion marine engines, 165, 166, 167
Iris and *Mercury*, first steel naval ships, 69
Iron first adopted in shipbuilding, 29
Iron ship building, advantages over wood, 40
Ironside, early iron sailing ship, 38

Japanese shipbuilding, 182
Jenkins, Professor Philip, 119
"Joggling" of plate edges, 98
John Randolph, early iron steamer, 33
John, William, on water-ballast steamers, 53
Jouffrouy, Marquis de, and early steamers, 17

Kaiser Wilhelm II., German liner, 66, 154
King Edward, pioneer turbine passenger steamer, 143
Kirk, Alex. C., and triple expansion engines, 78

Labour, high price of, 188
Labour-saving tools, 190, 191
Lady Lansdowne, early iron steamer, 33
Lairds, of Birkenhead, and early iron steamers, 33
La Savoie and *La Touraine*, French liners, 64
Launching ships, the responsibility of, 112
Lifting and transporting facilities in shipyards, 102, 106
Liquid fuel, 160
Lloyd's Register of Shipping, founding of, 37
— — and steel for shipbuilding, 71
Lobnitz and Co., Renfrew, and steam dredgers, 132
Londonderry, turbine channel steamer, 146
Loongana, turbine steamer, 149
Lorena, turbine steam yacht, 147
Lucania and *Campania*, Cunard liners, 65

Majestic and *Teutonic*, White Star liners, 63
Marjory, pioneer channel steamer, 24
Manchuria and *Mongolia*, American liners, 74
Manxman turbine channel steamer, 146
Martell, Benjamin, on bulkhead doors, 57
Materials, raw, for shipbuilding, 167, 169
Mercury and *Iris*, first steel naval ships, 69

Mersey, the, as a shipbuilding centre, 175
Midland Railway Co.'s steamers, 145
Miller, Patrick, and early steamers, 19
Minnesota, American steamer, 74
Models, experiments with ship, 82, 84, 85
Motor launches, high speed, 165
Mould-loft, operations in, 89

Napier, David and Robert, 23, 25, 26
— Robert, and early Cunarders, 44
Navigators, Chinese and Cretans as, 5
— Grecians and Romans as, 5
Nickel-steel in shipbuilding, 44, 73
Noah's Ark, 2, 3
Normannia, Hamburg-American liner, 64
North-German Lloyd liners, 64, 66
Novelties in ship design, 135

Oceanic, White Star liner, 67
Ogden, Francis B., early screw steamer, 45
Oil fuel on board ship, 160, 162
— Howden's system, 163
— Korting's system, 163
Oil motors in small craft, 164, 165
Output of tonnage, annual, 179, 181, 186
Ores for shipbuilding material, 169

Papin, Denis, and early steamboats, 16
Parisian, Allan liner, 70
Parsons marine steam turbine, 139, 141
Persia, first iron Cunard liner, 47
Pett, Phineas, Master Shipwright, 10, 11
Phœnicians, ships of the, 4, 5
Pioneer iron ocean steamers, 34
Pneumatic riveters and riveting, 103, 107, 112, 191
Pressures, steam-boiler, 78
Prince Albert, first Tyne-built iron steamer, 32
Prince Royal, naval ship of 1620, 10
Princess Royal, early iron deep-sea steamer, 34
Punching and shearing of plates, 95

Quebec, early St. Lawrence steamer, 26
Queen Alexandra, turbine river steamer, 144
Queen, turbine channel steamer, 145

Rainbow, early iron deep-sea steamer, 34
Ramage and Ferguson, and turbine yachts, 147
Rankine, Prof. Macquorn, 36
Raw materials for shipbuilding, 167, 169
Registers of shipping, 38, 39
Riley, James, and steel for shipbuilding, 69
Riveting, the work of, 99, 106, 108
— by hydraulic and pneumatic power, 106
Rivet-holes, punching the, 95
Rob Roy, pioneer channel steamer, 25
Robertson, John, and early marine engines, 23, 25
"Roller" ships, 136
Rome, galleys of, 5
Rotomahana, first ocean-going steel steamer, 70
Royal George, early iron ocean steamer, 34
Royal Sovereign, first deep-sea iron steamer, 34
Royal William, first steamer to cross Atlantic, 27
Rumsey, James, and early steamboats, 17
Russell, Scott, and *Great Eastern*, 35, 49
Russell and Co., Port Glasgow, work of, 176

Sailing ships, proportion of, to steamers, 179
— fast clipper, 42
Savannah first uses steam on the Atlantic, 27
Scotia, last Cunard paddle steamer, 47
Scott Russell, and his work, 35, 49, 83
Screws first applied to steamers, 18
Screw-propulsion established, 45
— advantages of, 48
"Scrive Board," preparing the, 89
Seppings, Sir Robert, and improvements in shipbuilding, 12
Servia, Cunard liner, 62, 63
Shearing and punching machines, 95
Shipbuilding a thousand years ago, 7
— wood, in America, 171
— and subsidiary industries, 172
— steel, introduction of, 68
Shipwrights' prejudices against iron shipbuilding, 37, 41
Simons and Co., William, Renfrew, and steam dredgers, 132
Sirius, pioneer Atlantic steamer, 27
Sivewright, C. W., and flanging and riveting plates, 101
Smith, Thomas Pettit, and screw-propulsion, 45
Solent, the, and wood shipbuilding, 170
Sovereign of the Seas, early naval ship, 12
Speed trials on the "measured mile," 118
Statistics of tonnage output, 179, 181, 186
Steam first applied to ship-propulsion, 16, 20
Steel shipbuilding, introduction of, 68
— — advantages of, 71, 72, 73
— plates of great length, 121, 122
Stephen, Alexander, and composite ships, 42
Stephen, Alex., and Sons, and Allan liners, 149
— Fred. J., and turbine steam yachts, 147
Stephenson, George, and iron ships, 30
St. Louis and *St. Paul*, International liners, 65
St. Lawrence, the, first steamers on, 26
Stevens, John, and early steamboats, 18
Strength calculations of iron ships, 36
Subdivision of ships by bulkheads, 54
Submarine vessels, 134
Suez Canal, effects of opening of, 43
Surface condensing engines, introduction of, 77
Swan Hunter and Wigham Richardson, 105, 156
Symington, William, and early steamboats, 19, 21

Taylor, Alexander, and triple-expansion engines, 78
Tea clippers, composite, 42
Teutonic and *Majestic*, White Star liners, 63
Thermopylæ, composite tea clipper, 43
Thomas Cranage, American wood steamer, 14
Tod and Macgregor, and early iron ocean steamers, 34
Tonnage, annual output of, 168, 179, 181, 186
Trevithick, Richard, and iron ships, 30
Trial, the first iron vessel, 29
Triple- and quadruple-expansion engines, 77, 78
— screw steamers, 136
Triremes of Rome, 5
Tubal Cain, first composite ship, 42
Turbine, steam, working principle of, 139

Turbine propulsion, initiation of, 139
Turbinia, pioneer turbine steamer, 141
— Canadian lake turbine steamer, 147
Turret-deck steamers, Doxford's, 127
Twin-screw steamers, first ocean-going, 63, 138
— — comparative safety of, 61
Tyne, Wear, and Tees as ship-building centres, 175, 176

Umbria and *Etruria*, Cunard liners, 63
Union S. S. Co. of New Zealand and steel ships, 70, 149, 152
— and turbine steamers, 149
United Kingdom, shipbuilding, 179, 186
United States, shipbuilding, 186

Velox, turbine torpedo-boat destroyer, 148
Vickers, Sons, and Maxim and crane equipment, 105
— and submarine vessels, 134
Victorian and *Virginian*, first turbine Atlantic liners, 76, 151
Vikings, the ships of, 6, 7, 8
Viking, turbine channel steamer, 150
Viper and *Cobra*, turbine torpedo-boat destroyers, 142
Vulcan, first iron vessel built in Scotland, 30
Vulcan Co., Stettin, and fast Atlantic liners, 75

Wallsend Slipway and Engineering Co. and oil fuel, 161
Wallsend Slipway and Engineering Co. and Cunard liners, 157
War vessels of Greece and Rome, 5
— of the Vikings, 6
Water-ballast in steamers and sailing ships, 52
Water-tube boilers, 78
Wave-line theory of Scott Russell, 83
Wear, Tees, and Tyne, as ship-building centres, 175, 176
Weymouth, Bernard, and composite ships, 43
"Whaleback" steamers, 128
White, Sir W. H., on oil fuel, 161
— on I. K. Brunel, 50
— on internal combustion engines, 166
— on twin and triple screws, 137
White Star liners *Britannic* and *Germanic*, 62, 63
Wilkinson, John, and iron vessels, 29
Williamson, Captain John, and turbine steamers, 143
Wilson, Thomas, builder of the *Vulcan*, 30
Wood, John, and early steamboats, 23
Wood shipbuilding, 14, 171
Wood steamer *Thomas Cranage*, 14
Workman, Clark, and Co., and turbine liners, 149
Workmen and labour-saving tools, 190, 191
— employed in shipbuilding, 172

Yarrow and Co. and turbine steamers, 147
— and high-speed launches, 165

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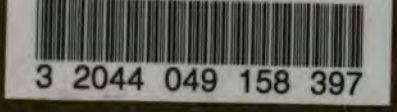
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